SYSTEM DESCRIPTION

Appendix 1

Kwang San Co., Ltd.

CONTENTS

I. TECHNICAL MANUAL

1. PRODUCT SPECIFICATION

1) Type: Filter + UV
2) Capacity: 250 ± 5 m^3/h
3) Specification of main components

Main components	Specifications
UV system	Maker: Kwang San Co., Ltd. Materials: SUS316L Power consumption: max. 49 kW Lamp quantity: 6 EA
UV lamp	Lamp type: Medium pressure UV lamp Arc length: 550 mm Overall length: 665 mm Power consumption: max. 8.1 kW/lamp
UV sensor	Output range: 0~200 mW/cm^2, 0~1,000 mW/cm^2 Materials: SUS316L Wavelength range: 220~280 nm Measurement point: Vertically longest and shortest distances from the lamp
Filtration system	Maker: Kwang San Co., Ltd. Mesh type : Wedge wire Mesh size : 50 μm Cleaning technology: Automatic back-flushing Differential pressure: 0.5 bar (adjustable) Power consumption: 9.5 kW

2. DESCRIPTION ON LAND-BASED TEST FACILITY

Ballast water is treated in ballasting and de-ballasting processes. During ballasting operation, most of aquatic organisms and particles larger than 50 μm in the ballast water are strained out through the filter. In addition, aquatic organisms that had not been removed by filtration process are disinfected while passing through UV system. Also, in order to remove aquatic organisms that may have survived from ballasting operation in the ballast tank, the ballast water is treated one more time using UV system during de-ballasting operation.
Figure 1 and 2 briefly show ballasting and de-ballasting processes of the BioViolet™.

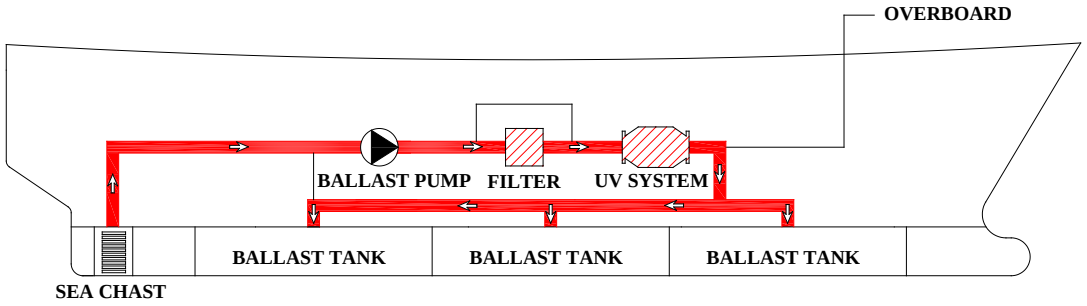


Figure 1. Schematic process diagram of the BioVioletTM at ballasting process

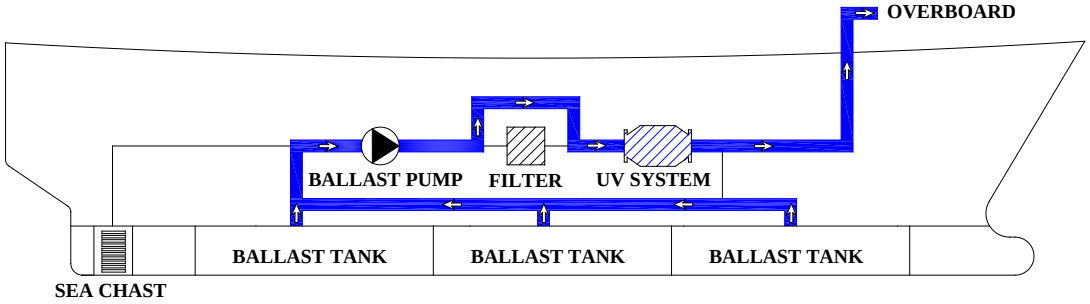


Figure 2. Schematic process diagram of the BioVioletTM at de-ballasting process

2.1 System components

1) Filtration System

Filtration system strains out most of aquatic organisms and particles larger than 50 μm in ballast water coming in through ballast pump, both increasing disinfection efficiency of UV system and preventing breakage of quartz tubes that protect UV lamps.

2) UV System

Ultraviolet light is largely classified into UVA (320~400 nm), UVB (280~320 nm), UVC (200~280 nm), and vacuum UV (100~200 nm) according to wavelength. Energy from ultraviolet light resulting in UVC region between 200~280 nm is known to inactivate microorganisms by damaging DNA and RNA of organism.

Although 260 nm is the wavelength that shows highest effect of disinfection, 254 nm is generally known as main germicidal wavelength since it shows greater output efficiency due to characteristics of the lamp.

Disinfection by ultraviolet light aggravates metabolic functions of the organism like reproduction through changes in the organism's DNA caused by absorption of photons with ultraviolet energy. Also depending on the type of organisms, UV dose and germicidal wavelength range for disinfection somewhat differ. Therefore in BioVioletTM, medium pressure UV lamp which emits polychromatic UVC spectrum was used.

2.2 Treatment process for each operation

The control system of the test facility uses flow information acquired from flow meter during ballasting and de-ballasting processes for real-time control of the ballast pump to maintain flow of the main pipe at 250 m^3/h during each operation mode.
While testing brackish water (3~32 PSU) and sea water (> 32 PSU) twice individually, UV system was operated at maximum power to perform chemical analysis, aquatic toxicity test and efficacy test under maximum UV dose condition. Also on remaining tests, power of UV lamp was controlled for sustained maintenance of UV intensity from UV intensity sensor within the range of 38 ~ 100 mW/cm^2 for efficacy test.

Flow rate	250 ± 5 m^3/h (no back-flushing)			
Treated volume	more than 200 m^3			
Treatments	Ballasting operation		Filter + UV system	
	De-ballasting operation		UV system	
Power consumption	max. 49 kW for UV system			
	max. 9.5 kW for filtration system			
	max. 1.5 kW for control system			
Salinity	Sea water		33.23~34.11 PSU	
	Brackish water		19.77~20.31 PSU	
UV transmittance	77~92 % (calculated value by two UV sensors)			
UV intensity control or lamp power	1st	Ballasting	8.1 kW/lamp	max. power
		De-ballasting	8.1 kW/lamp	max. power
	2nd	Ballasting	100 mW/cm^2	Intensity control
		De-ballasting	93 mW/cm^2	Intensity control
	3rd	Ballasting	8.1 kW/lamp	max. power
		De-ballasting	8.1 kW/lamp	max. power
	4th	Ballasting	70 mW/cm^2	Intensity control
		De-ballasting	70 mW/cm^2	Intensity control
	5th	Ballasting	45 mW/cm^2	Intensity control
		De-ballasting	45 mW/cm^2	Intensity control
	6th	Ballasting	8.1 kW/lamp	max. power
		De-ballasting	8.1 kW/lamp	max. power
	7th	Ballasting	8.1 kW/lamp	max. power
		De-ballasting	8.1 kW/lamp	max. power
	8th	Ballasting	60 mW/cm^2	Intensity control

		De-ballasting	60 mW/cm^2	Intensity control
	9th	Ballasting	45 mW/cm^2	Intensity control
		De-ballasting	45 mW/cm^2	Intensity control
	10th	Ballasting	38 mW/cm^2	Intensity control
		De-ballasting	38 mW/cm^2	Intensity control
	11th	Ballasting	40 mW/cm^2	Intensity control
		De-ballasting	40 mW/cm^2	Intensity control

* 11th: high turbidity

2.2.1 Test preparation

Prior to ballasting operation, sea water that passed through strainer is filled in tank 1 and tank 2 by sea water pump. The amount of sea water filled differs according to the test condition (sea water or brackish water). In case of brackish water test, fresh water is additionally filled in each tank in order to adjust salinity of test water. Also to satisfy influent condition of IMO guidelines before the test, identical amounts of starch, glucose, silica granule, phytoplankton, zooplankton and heterotrophic bacteria are additionally added to tank 1 and tank 2.
In addition, agitator 1 of tank 1 and agitator 2 of tank 2 are operated during ballasting process, and agitator 2 of tank 2 and agitator 3 of tank 3 are operated during de-ballasting process, so that the test water in each tank is homogeneous.

- Checklist: System operator must check the following before operation.
  - Breaker, controller, sensors, filter, UV system, ballast pump, and agitators
  - Switch operation mode of the main controller of the test facility and the controller of BioViolet™ to ‘Remote’
  - Leakage and failure of various valves, and etc.

2.2.2 Pre-operation (ballasting and de-ballasting operation)

The scope of control of BioViolet™ is as shown in Figure 3.

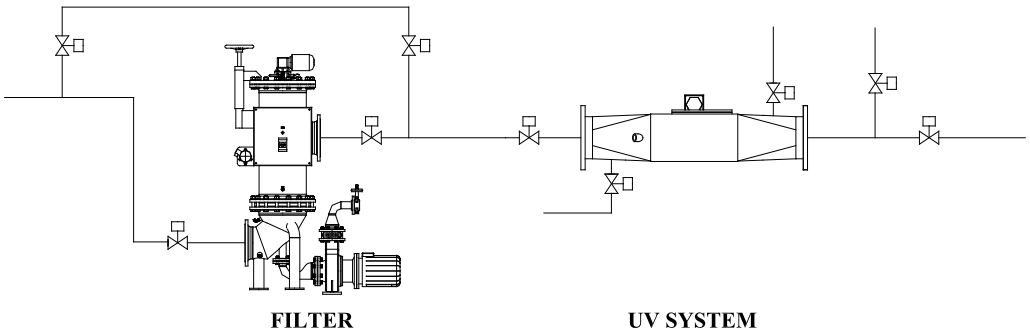


Figure 3. The scope of control of BioViolet™

- Pre-ballasting operation

When “Pre-ballasting (T) Mode” is turned ON by the operator, the main controller of the test facility (ship’s AMS) opens valves on ballasting (T) line of the test facility. Then, it transmits “Pre-ballasting Mode ON” signal to the BioVioletTM controller. When the BioVioletTM controller receives “Pre-ballasting Mode ON” signal, inlet and outlet valves of the fresh water line in the UV system are opened, executing the pre-heating process for UV lamp.

In Figure 4, water in the main pipe of the test facility was indicated as red, and water of fresh water line for pre-heating of UV lamp was indicated as blue. Here, an actual ship can use sea water line of “Sea Chest→ UV system → Overboard” as pre-heating line, or install a separate fresh water line for use as pre-heating line. Currently, the test facility is using fresh water for pre-heating process.

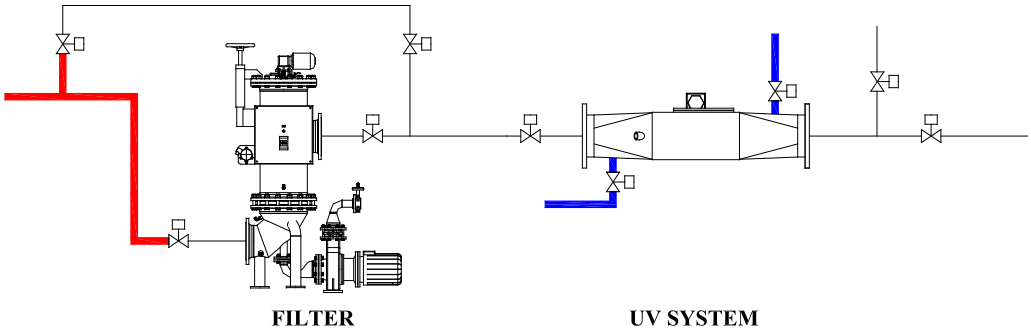


Figure 4. Pre-heating process

Once pre-heating of UV lamp is complete, the BioVioletTM controller opens the valves from the front side of the filter to rear end of the UV system, as shown in Figure 5. Here, the test facility controller executes “Ballasting (T) Mode” by operating ballast pump.

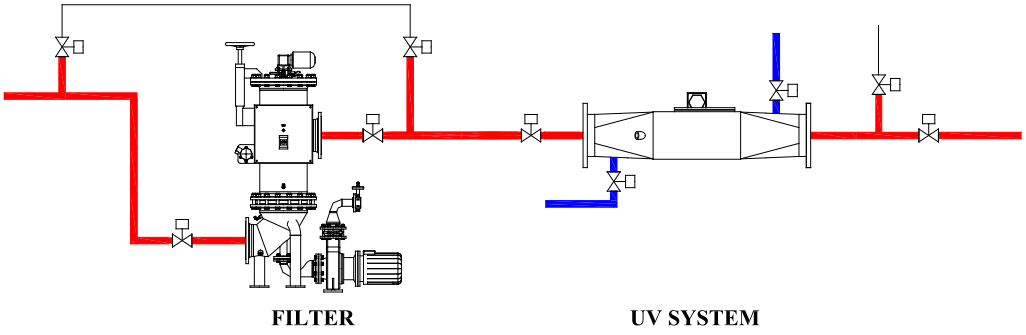


Figure 5. Ballasting mode ON

Also if flow of the main line is above the setting, the BioVioletTM controller completes pre-heating process by closing inlet and outlet valves of fresh water line in the UV system, as in Figure 6.

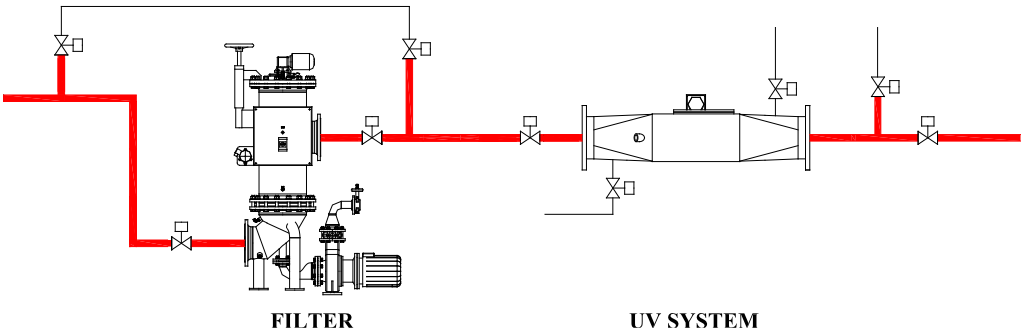


Figure 6. Closure of valves on fresh water line

- Pre-de-ballasting operation

Once “Pre-de-ballasting (T) Mode” is turned ON by the operator, the main controller of the test facility opens valves on de-ballasting (T) line and transmits “Pre-de-ballasting Mode ON” signal to the BioVioletTM controller. Then, after the BioVioletTM controller receives “Pre-de-ballasting Mode ON” signal, it executes pre-heating process of UV lamp by opening inlet and outlet valves of fresh water line in the UV system.

In Figure 7, water in the main pipe of the test facility was indicated as red, and water of fresh water line for pre-heating of UV lamp was indicated as blue. Here, an actual ship can use sea water line of “Sea Chest→ UV system → Overboard” as pre -heating line, or install a separate fresh water line for use as pre-heating line. Currently, the test facility is using fresh water for pre-heating process.

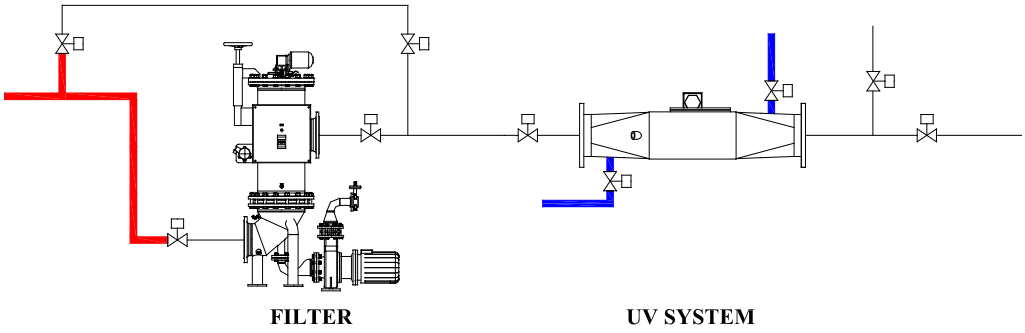


Figure 7. Pre-heating process

Once pre-heating of UV lamp is complete, the BioVioletTM controller opens the valves from the front side of the filter to rear end of the UV system, as shown in Figure 8. Here, the test facility controller executes “De-ballasting (T) Mode” by operating ballast pump.

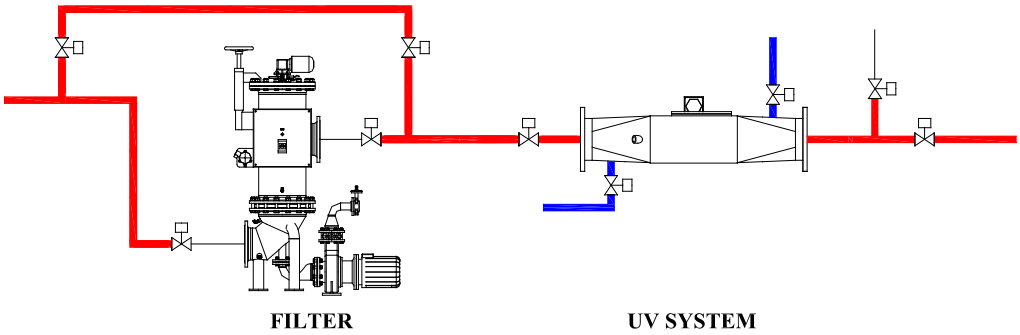


Figure 8. De-ballasting mode ON

Also if flow of the main line is above the setting, the BioVioletTM controller completes pre-heating process by closing inlet and outlet valves of fresh water line in the UV system, as in Figure 9.

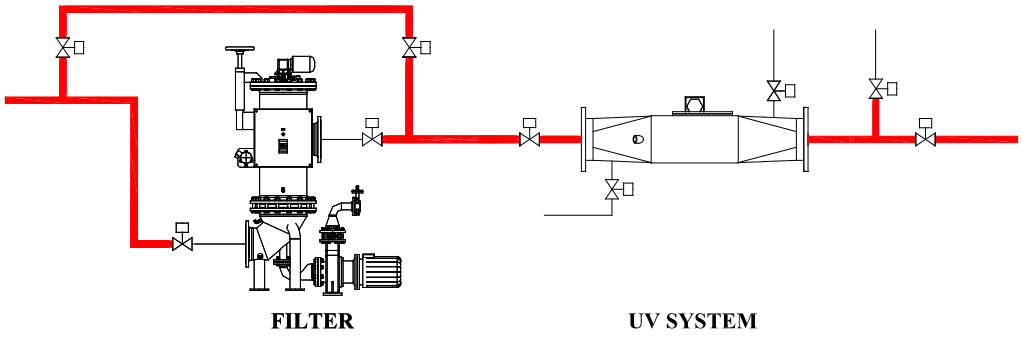


Figure 9. Fresh water line valves closure

2.2.3 Ballasting operation

- Treated water

Ballasting operation on the treated water begins with “Ballasting (Treated) Mode ON” signal from the main controller of the test facility. Test water in tank 2 that satisfies the IMO guidelines passes through the filter and UV system by ballast pump and is transferred to tank 3. In this process, flow meter is used for real-time control of ballast pump to maintain flow of the main pipe at 250 m^3/h.

The filter primarily strains out aquatic organisms and particles in the test water over certain size (50 μm). The UV system disinfects any aquatic organisms that had not been removed by the filter using germicidal wavelength.

In Figure 10, red line represents the transfer path of the treated water during ballasting operation. Sampling is performed three times by KOMERI during ballasting operation.

□ Transfer path of the treated water: Tank 2 → Ballast pump → Flow meter → Filter → UV system → Tank 3

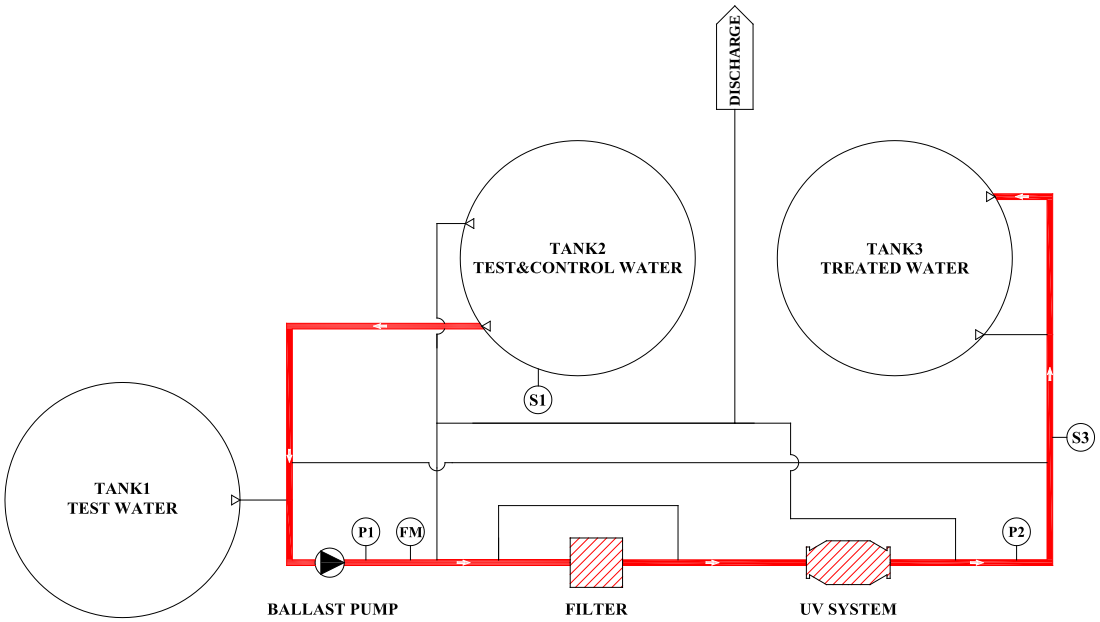


Figure 10. Ballasting operation of the treated water

- Control water

Ballasting operation on the control water begins by the main controller of the test facility after opening main pipe valves and controlling ballast pump. The test water is transferred from tank 1 to tank 2 by ballast pump. In this process, flow meter is used for real-time control of ballast pump to maintain flow of the main pipe at 250 m^3/h.

In Figure 11, blue line represents the transfer path of the control water during ballasting operation. Sampling is performed three times by KOMERI during ballasting operation.

□ Transfer path of the control water: Tank 1 → Ballast pump → Flow meter → Tank 2

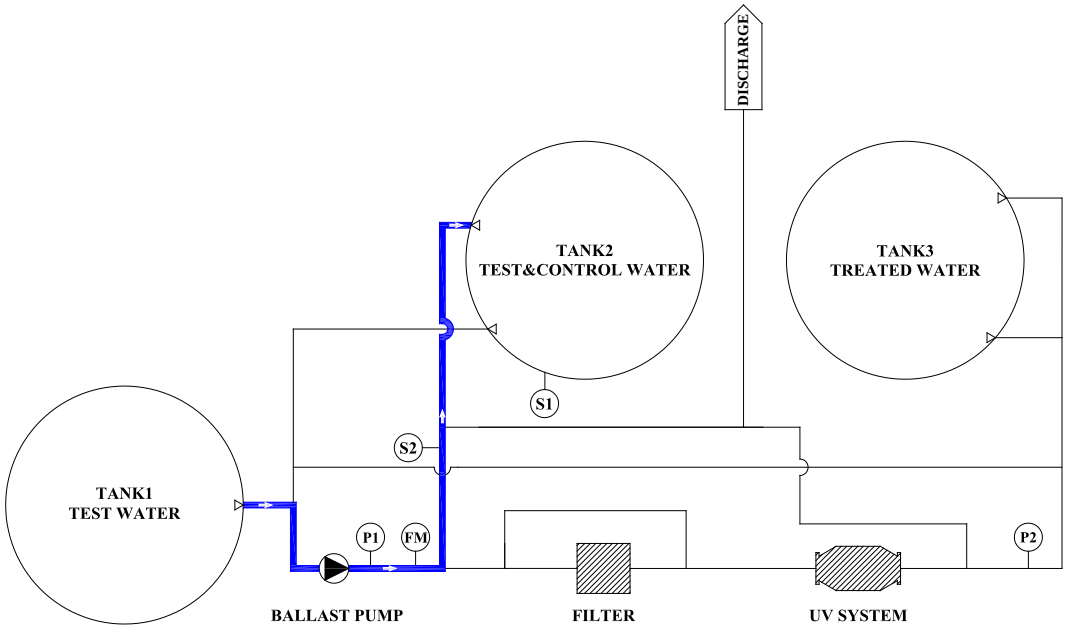


Figure 11. Ballasting operation of the control water

2.2.4 De-ballasting operation

- Treated water

De-ballasting operation for the treated water begins with “De-ballasting (Treated) Mode ON” signal from the main controller of the test facility. The treated water in tank 3 is discharged by ballast pump after passing by the UV system. In de-ballasting operation, filter is not used while the treated water is being discharged, but the UV system is used once again to disinfect any aquatic organisms that were not removed during ballasting process or can recover while the treated water is stored within ballast tank. In this process, flow meter is used for real-time control of ballast pump to maintain flow of the main pipe at 250 m^3/h.

In Figure 12, red line represents the transfer path of the treated water during de-ballasting operation. Sampling is performed three times by KOMERI during de-ballasting operation.

□ Transfer path of the treated water: Tank 3 → Ballast pump → Flow meter → UV system → Discharge

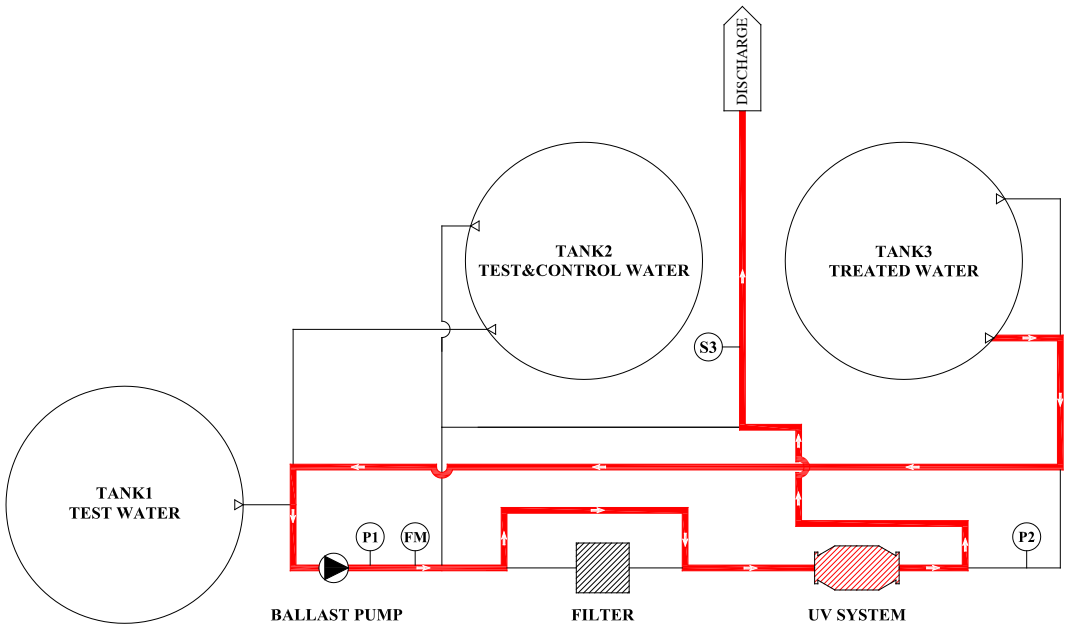


Figure 12. De-ballasting operation on the treated water

- Control water

De-ballasting operation of the control water begins by the main controller of the test facility after opening main pipe valves and controlling ballast pump. The control water in tank 2 is discharged by ballast pump. In this process, flow meter is used for real-time control of ballast pump to maintain flow of the main pipe at 250 m^3/h.

In Figure 13, blue line represents the transfer path of the control water during de-ballasting operation. Sampling is performed three times by KOMERI during de-ballasting operation.

□ Transfer path of the control water: Tank 2 → Ballast Pump → Flow meter → Discharge

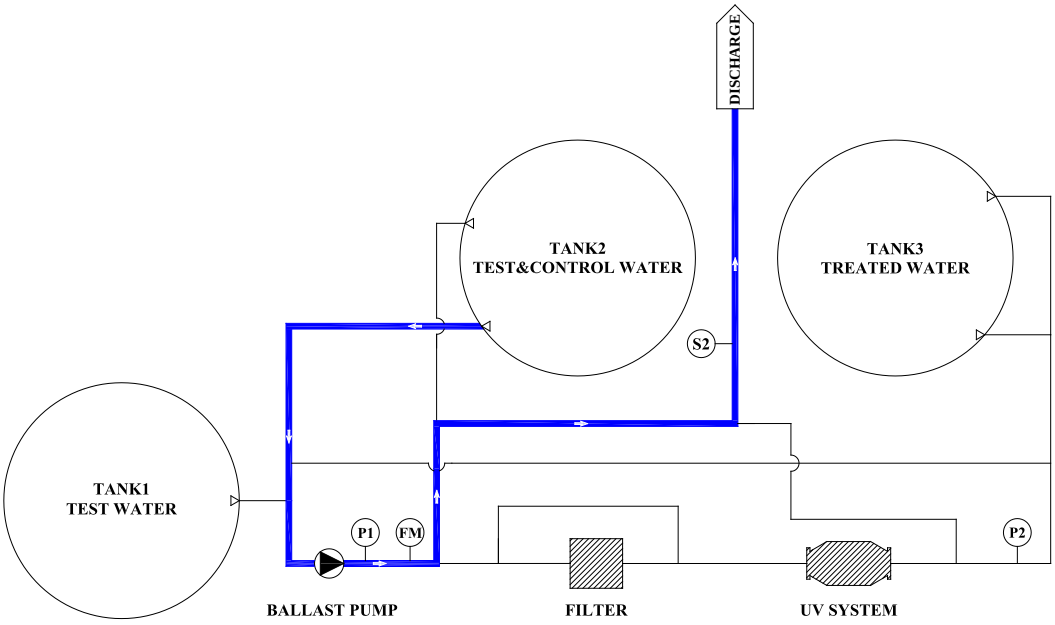


Figure 13. De-ballasting operation on the control water

2.2.5 Cleaning operation

When ballasting or de-ballasting operation is done, the BioVioletTM controller closes front and rear valves of the UV system and fills the chamber with fresh water by opening fresh water line valves of the UV system. Also, once the chamber is completely filled with fresh water, cleaning device is operated to clean the quartz tube. Such cleaning operation is handled by the controller.

2.3 System control procedure

Below is the procedure for BioVioletTM operation. Given signals do not completely coincide with instructions used by the land-based test facility because several procedures were added or modified for use in ships.

2.3.1 Minimum signals for remote control

1) Signals from a ship's automation system to the BWMS

① Remote mode on request: Digital
② Start ballast request: Digital
③ Stop ballast request: Digital
④ Start de-ballast request: Digital
⑤ Stop de-ballast request: Digital
⑥ Heavy consumer feedback: Digital
⑦ Remote mode off request: Digital
⑧ Ballast pump running feedback: Digital
⑨ Reset alarm: Digital

⑩ BWMS by-pass request: Digital
⑪ EM'CY stop: Digital
⑫ Main pipeline flow rate: Analog 4~20 mA

2) Signals from the BWMS to a ship's automation system
① Remote mode standby OK: Digital
② Heavy consumer request: Digital
③ Lamp on & warm up: Digital
④ Ballast pump start possible: Digital
⑤ Ballast pump stop possible: Digital
⑥ Running ballasting: Digital
⑦ Running de-ballasting: Digital
⑧ Running by-pass: Digital
⑨ BWMS stop OK: Digital
⑩ Common shutdown: Digital
⑪ Common alarm: Digital

2.3.2 Remote mode control (ship's AMS) in minimum signals

1) Ballast start control procedure

① Remote mode ON request

To use BWMS in remote (that is, ship's AMS), first check whether the selector switch of local control panel is set to remote mode. Ship's AMS transmits remote mode request signal to the BWMS controller.

② Remote mode standby OK

Once prepared to operate remote mode, BWMS outputs standby OK.

③ Start ballast request

Once standby OK signal comes in as a feedback, the operator selects start ballast request at the ship's AMS.

④ Heavy consumer request

Heavy consumer request for ship's power system.

⑤ Heavy consumer feedback

Feedback to standby OK for the power consumption.

⑥ UV lamp on & warm up

Inlet and outlet valves of pre-heating pipeline are automatically opened to turn on the UV lamp. The UV lamp is pre-heated for about 4~5 minutes. BWMS outputs warm up signal while pre-heating.

⑦ Ballast main valve open

When pre-heating of the UV lamp is complete, warm up signal disappears and main valves on ballasting line are automatically opened by the ship's AMS.

⑧ Ballast pump start possible

When all valves on ballasting main pipe are opened, BWMS outputs a signal to show that ballast pump can be operated.

⑨ Ballast pump start feedback

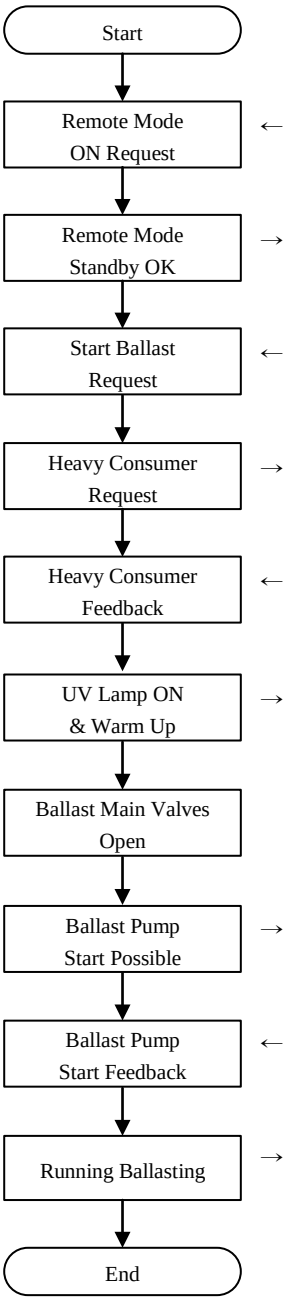
Ballast pump condition signal is sent from the ship's AMS to BWMS.

⑩ Running ballasting

Once all of the operation conditions above are satisfied, BWMS outputs a signal to show that it is being operated in ballasting mode.

← : The signal from ship's AMS to BWMS

→ : The signal from BWMS to ship's AMS



2) De-ballast start control procedure

① Remote mode ON request

To use BWMS in remote (that is, ship's AMS), first check whether the selector switch of local control panel is set to remote mode. Ship's AMS transmits remote mode request signal to the BWMS controller.

② Remote mode standby OK

Once prepared to operate remote mode, BWMS outputs standby OK.

③ Start de-ballast request

Once standby OK signal is returned as a feedback, start de-ballast request is selected.

④ Heavy consumer request

Heavy consumer request for ship's power system.

⑤ Heavy consumer feedback

Feedback to standby OK the power consumption.

⑥ UV lamp on & warm up

Inlet and outlet valves of pre-heating pipeline are automatically opened to turn on the UV lamp. The UV lamp is pre-heated for about 4~5 minutes. BWMS outputs warm up signal while pre-heating.

⑦ De-ballast main valve open

When pre-heating of the UV lamp is complete, warm up signal disappears and main valves on de-ballasting line are automatically opened by the ship's AMS.

⑧ Ballast pump start possible

When all valves on ballasting main pipe are opened, BWMS outputs a signal to show that ballast pump can be operated.

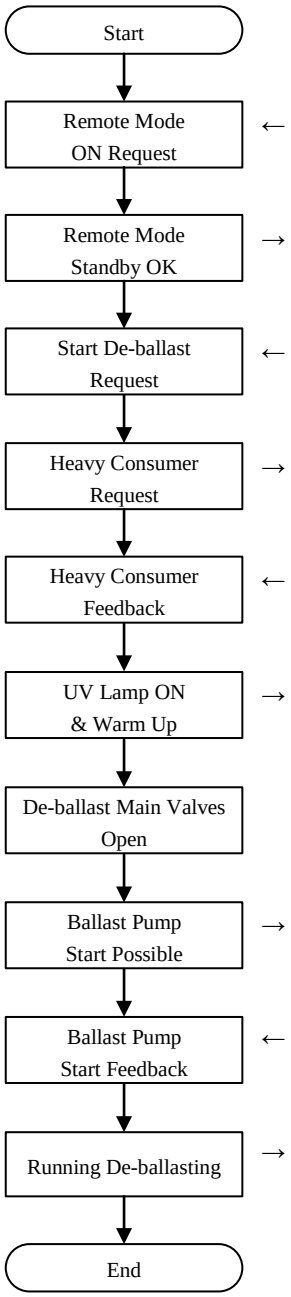
⑨ Ballast pump start feedback

Ballast pump status signal is sent from the ship's AMS to BWMS.

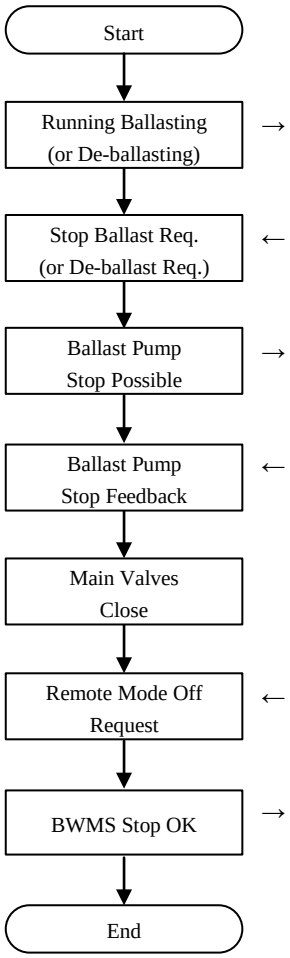
⑩ Running de-ballasting

Once all of the operation conditions above are satisfied, BWMS outputs a signal to show that it is being operated in de-ballasting mode.

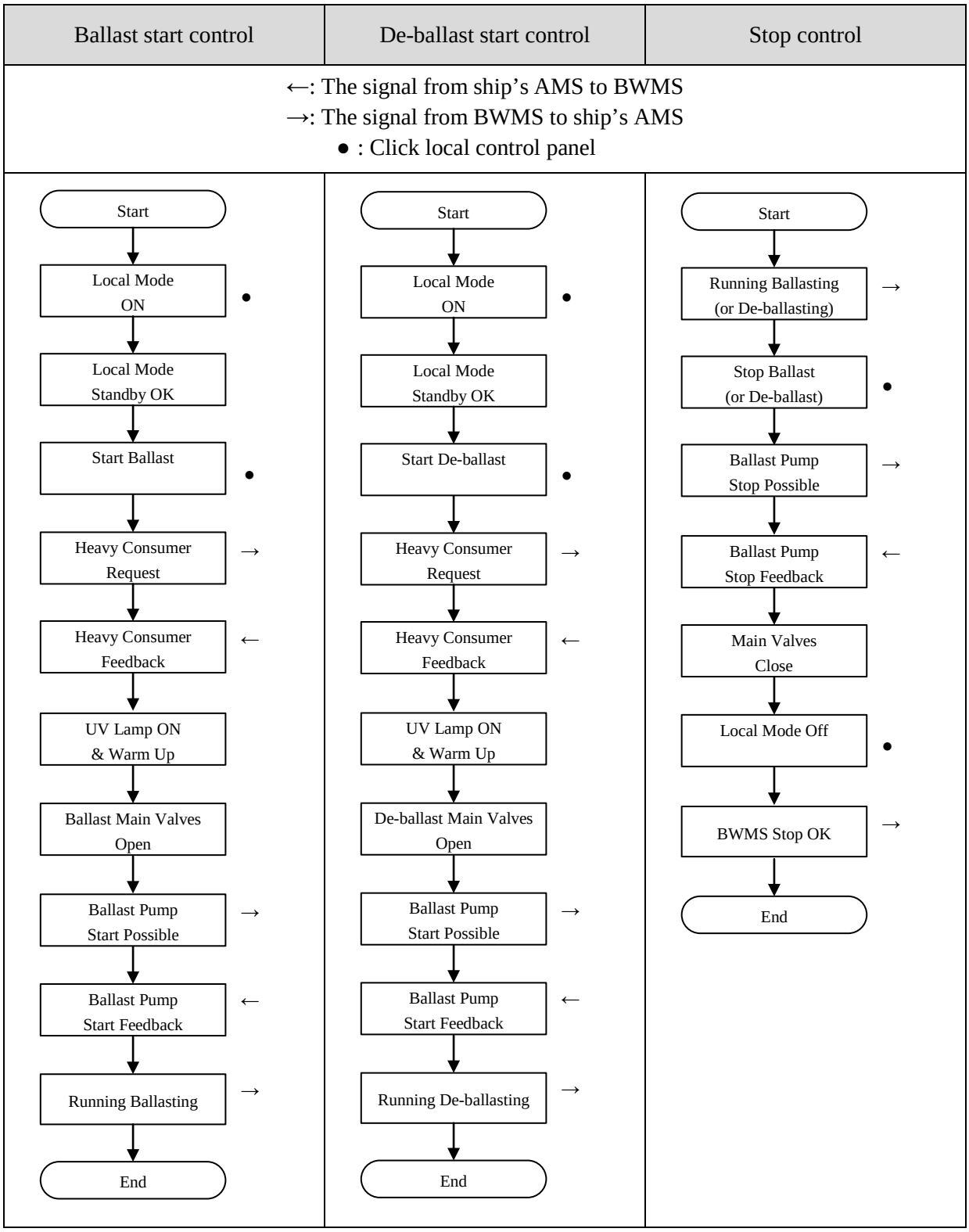
← : The signal from ship's AMS to BWMS
→ : The signal from BWMS to ship's AMS



3) Stop control procedure

① Running ballasting (or de-ballasting) Shows current operation status. ② Stop ballast (or de-ballast) request Stops ballast operation. ③ Ballast pump stop possible Stops ballast pump to stop operation. ④ Ballast pump stop feedback The ship's AMS stops ballast pump and transmits feedback signal to BWMS. ⑤ Ballast main valves close Once pump feedback signal is transmitted and flow is decreased, main valves are automatically closed. ⑥ Remote mode off request Mode is turned OFF for complete termination of operation. ⑦ BWMS stop OK Once the ship's AMS transmits mode off request signal, BWMS turns off the UV lamp after a certain period of time, outputs BWMS stop OK signal, and operates cleaning wiper. * After the mode off, about 3~4 minutes of delay time is required to restart operation.	← : The signal from ship's AMS to BWMS → : The signal from BWMS to ship's AMS 

2.3.3 Local control procedure



2.3.4 System alarms

BioVioletTM alarms are classified into alarm groups and numbers according to the areas and characteristics of each system.

1) Alarm groups

① General alarms : GS00
② Control system alarms : CS00
③ Lamp power unit alarms : LU00
④ UV chamber unit alarms : CU00
⑤ Filter unit alarms : FU00

2) Alarm description

① General alarms

Alarm ID	Display	Description	Check point
GS00	Main power off	- Level: Shutdown - Delay: 0 s - Disconnected 440/380 VAC power on MC panel, or Reactor panel	- Check the 440/380 VAC main power switch or voltage - Check the DI signal line
GS01	Control power off	- Level: Shutdown - Delay: 0 s - Disconnected 220 VAC power on MC panel, or Reactor panel	- Check the 220 VAC power switch or voltage - Check the DI signal line
GS02	EM'CY stop button	- Level: Shutdown - Delay: 0 s - Press the EM'CY stop button	
GS03	Main line flow signal missing	- Level: Alarm - Delay: 0 s	- Check the PLC analog input module & signal condition
GS04	Main line valve error	- Level: Shutdown - Delay: 0 s - Set point: 30 s - Main line valve moving time over	- Service air pressure check - Check the valve feedback signal cable
GS05	Pre-heating valve error	- Level: Shutdown - Delay: 0 s - Set point: 10 s - Feedback signal missing after valve order	- Service air pressure check - Check the valve feedback signal cable
GS06	Exceed main line flow rate	- Level: Alarm - Delay: 10 min - Set point: 250 m^3/h - Main line flow higher than the certified flow rate	- Check the PLC analog input module & signal condition - Reduce the flow

② Control system alarms

Alarm ID	Text	Description	Check point
CS00	UV lamp running time 2000 hr	- Level: Alarm - Delay: 0 s - Set point: 2,000 hr - Recommend to replacement the UV lamp	- Replacement the UV lamp
CS01	UV intensity low	- Level: Alarm - Delay: 0 s - Set point: 40 mW/cm^2 (sensor located at long distance) - No.1 UV sensor intensity is low	- UV intensity sensor check, or replace UV lamp
CS02	UV pre-heat time over	- Level: Shutdown - Delay: 0 s - Set point: 5 min - UV power increase time over	- UV power input PLC module check - Check the UV lamp installation condition or replace the lamp
CS03	UV lamp power low	- Level: Shutdown - Delay: 1 min - Set point: 3 kW - Decrease the UV lamp power abnormally	- UV power input PLC module check - Check the UV lamp installation condition or replace the lamp

③ Lamp power unit alarms

Alarm ID	Display	Description	Check point
LU00	Reactor panel temp. high	- Level: Alarm - Delay: 30 s - Set point: 50 ℃ - Reactor panel cool air temperature high	- Check the reactor panel cooling system - Check the temp. sensor condition in the panel - Cooling water circulation check
LU01	Reactor panel temp. high-high	- Level: Alarm - Delay: 30 s - Set point: 60 ℃ - Reactor panel cool air temperature high-high	- Check the reactor panel cooling system - Cooling water circulation check
LU02	UV reactor common shutdown	- Level: Shutdown - Delay: 0 s - Activate sensor inside reactor unit (mains failure, temp. high, lamp failure, earth failure)	- Mains failure: Replace the fuse inside the reactor unit or reactor unit - Disconnected main power on reactor unit - Temp. high: Check the reactor panel cooling system - Lamp failure: Lamp connection check, or replace the UV lamp - Earth failure: UV lamp power line or lamp cable insulation condition check
LU03	UV reactor common alarm	- Level: Alarm - Delay: 0 s - Activate sensor inside reactor unit (Fan failure, temp. alarm)	- Fan failure: Running check the fan in lamp on condition - Temp. alarm: Check the reactor panel cooling system

④ Chamber unit alarms

Alarm ID	Text	Description	Check point
CU00	Chamber water temperature high	- Level: Alarm - Delay: 30 s - Set point: 50 ℃ - Water temp. high in the chamber	- Check the water temp. in chamber
CU01	Pre-heating flow low	- Level: Alarm - Delay: 10 s - Set point: 5 m^3/h - Low flow rate of fresh water	- Fresh water pressure & valve condition check
CU02	Cleaning wiper long run	- Level: Alarm - Delay: 0 s - Set point: 2 min - Cleaning device moving time limit	- Check the cleaning motor, or proximity sensor condition - Cleaning motor power cable check
CU03	Cleaning motor over current	- Level: Shutdown - Delay: 0 s - Over current sensor activate	- Cleaning motor condition & over current sensor check

⑤ Filter unit alarm

Alarm ID	Text	Description	Check point
FU00	Diff. press. high	- Level: Shutdown - Delay: 20 s - Set point: 0.8 bar - Diff. press. high sensor activate	- Recommend cleaning the filter elements - Check the filter diff. press. switch condition
FU01	Pump motor over current	- Level: Alarm - Delay: 0 s - Over current sensor activate	- Pump motor condition & over current sensor check
FU02	Gear motor over current	- Level: Alarm - Delay: 0 s - Over current sensor activate	- Gear motor condition & over current sensor check
FU03	Back flushing long run	- Level: Alarm - Delay: 0 s - Set point: 30 s - Back flush running time limit	- Check the motors & proximity sensor condition - Motor power cables check
FU04	Filter element center failure	- Level: Alarm - Delay: 0 s - Set point: 30 s - Sensor digital input signal missing	- Proximity sensor & signal cable condition check

3. INSTALLATION SPECIFICATION

1) Positioning of filter and UV system
   - Filter is first installed on the fluid path on the rear of ballast pump, and the UV system is installed on the rear of filter and by-pass line that are installed in parallel.

2) Filter and by-pass line
   - Since filter is only used in ballasting process of the treated water, by-pass line must be installed in parallel.
   - Automatic valves are installed on inlet and outlet of parallel by-pass line for automatic conversion of path according to operation mode.

- Inlet and outlet of by-pass pipeline are connected using a flange.
- Back-flushing line connected to the rear of back-flushing pump should be maintained straight if possible, and water hammer arrester is installed if necessary.
- Capacity of back-flushing pump should be selected according to the system spec.
- Power supplies including breaker must be turned OFF when wiring electric systems (motors, pumps, sensors, etc.).
- When disassembling and reassembling filter element, make sure that elements completely adhere.
- After assembly of the filter, perform leakage test.

3) UV system
- UV lamps must be installed horizontally.
- While maintaining horizontality of the UV lamps, the UV chamber may be installed vertically or horizontally.
- After chamber assembly, leakage test is performed.
- When disassembling or assembling quartz tubes and UV lamps, work must be carried out with special care not to damage them and while maintaining horizontality.
- When operating cleaning device, take care not to damage quartz tubes and UV lamps.
- When conducting works related to components inside the chamber such as quartz tubes, UV lamps and cleaning device, water in the chamber must be drained first.
- Wiring of the power line supplied to ballasts and UV lamps must be performed by an electric expert.
- Disassembly and assembly of UV lamps and ballasts must be done with the breaker OFF.
- When manually checking the output of UV system, power is increased gradually from minimum power to maximum power. Power by ballasts shall not exceed power described in the design spec.
- For stability of output, ballasts and UV lamps are positioned within shortest possible distance.
- Ballasts must be firmly attached to a rack for horizontality.

4. SYSTEM LIMITATIONS

- Processing capacity: 250 ± 5 m^3/h
- Minimum flow: 30 m^3/h
- Surrounding temperature: 0~55 °C
- Relative humidity: max. 90 %
- Compressed air: min. 5.5 kg/cm^2
- Power consumption
  - UV system: max. 49 kW
  - Filtration system: max. 9.5 kW
  - Control system (with power panel): max. 1.5 kW
- Power
  - Main power: 380 VAC or 440 VAC (50 or 60 Hz)
  - Control power: 220 VAC, 24 VDC

5. MAINTENANCE AND REPAIR PROCEDURES

5.1 Maintenance

1) Filtration system
- Inspect operation status of water hammer arrester during each test period.
- If necessary, wash elements. When elements are being installed, assembling the filter without complete installation may result in damaging of elements. The filter must be assembled after completing installation of elements.
- Leakage status is inspected.
- Sensor operation status is inspected during each test period or with power ON.

2) UV system
- Leakage status of the chamber is inspected during each test period.
- Sensor operation status is inspected during each test period or with power ON.

3) Control system (with power panel)
- Ballast status is inspected during each test period or with power ON.
- Prior to testing, all electric systems within the control scope of BioVioletTM are inspected.

5.2 Repair

1) Filtration system
- If the filter does not perform automatic back-flushing despite the increase in main pipe pressure, immediately stop the system, inspect the status of pressure meter attached to the filter, and replace it if there is abnormality. When there is no problem in the pressure meter, back-flushing pump and automatic valve of back-flushing line are inspected.
- In case of leakage in the assembly, separate the upper part of the filter and check assembly status of elements. Firmly reassemble the upper part if there is no abnormality in the assembly of elements.
- If sequential cleaning process for elements is not executed during automatic back-flushing, stop the system operation, inspect the status of proximity sensor and motor, and replace them if necessary.

2) UV system
- When alarm signal is received from ballast, inspect the UV lamp status and replace it if necessary. Also when disassembling or assembling components inside the chamber, work must be carried out with special care not to damage quartz tubes and UV lamps, and while maintaining horizontality.
- In case of leakage in the chamber, check the assembly and firmly reassemble.
- If abnormal signal is detected by the sensor installed in the chamber, inspect the status of sensors, UV lamps and ballasts before replacing any necessary components.
- When conducting works related to components inside the UV chamber such as quartz tubes, UV lamps and cleaning device, water in the chamber must be drained first.

6. RISK PREVENTION AND MEASURES

BioViolet™ gives information to the crew by attaching safety marks on components based on the risk level determinate for any operation or access that is risky to safety of the ship and crew.

1) UV lamp damage

When lamp is damaged, the lamp must be disposed with protective gloves and clothing on since there may be residual mercury. Sufficiently ventilate the environment because mercury evaporates at room temperature.

① Neutralize any parts suspected of residual mercury such as the lamp and chamber using calcium sulfide or sodium thiosulfate.

② Damaged lamp is disposed with protective gloves and clothing on, and moved to chemical waste disposal facility on the ship after sealing.

③ If water that may contain residual mercury contacts eyes or skin, wash with running water.

2) Chamber inspection

When works such as damaged quartz tube, cleaning wiper inspection, replacement of various seals, and sensor inspection are carried out, follow the procedure below.

① If UV system was in operation, wait at least 5 minutes for cooling.

② Conduct UV chamber inspection with all water in the chamber drained and power turned off.

③ Protective gloves must be worn during inspection.

3) Exposure to ultraviolet light

When skin is exposed to ultraviolet light, erythema, pigmentation, and skin cancer may occur. Therefore, if a work must be carried out with UV lamp turned on, take sufficient care not to expose eyes or skin to ultraviolet light. Especially, face must be protected (shaded glasses or UV blocking mask).

4) Storage of UV lamp

- Protect the UV lamp from damage during storage using materials with impact resistance.
- Always store the lamp horizontally.

5) Replacement of UV lamp

- Wear cotton gloves when replacing the lamp.
- Maintain the surface of the lamp clean from impurities.
- Take care in replacement of the lamp because lamp may be damaged from impact.
- The lamp must always be maintained horizontally.

6) Disassembly and assembly of filter

- When separating the upper part of the filter for replacement, inspection or cleaning of filter element, wear safety cap since head may be injured.
- If assembly of the filter is incomplete, leakage may occur at the upper part of the filter. Therefore, do not position products that should not contact water (electric products, other dry materials) around the filter during first operation after assembly.
- Filter element can cause wounds on human body if the element contacts human body during transportation.

Physical impact on the element may damage the element and reduce filtering efficiency. Hence, elements must be transported while paying attention to physical impacts

7) Electric shock

Since electric systems such as the controller and distributing board can cause electric shock in human body, any inspections must be performed by an electric expert. Use electroscope to check for charge status of electric charge in electric components. Also in order to secure safety of human body, wear safety cap, rubber gloves, rubber boots and insulating clothes.

However, if an electric shock is observed, follow the procedure below.

① Turn off the breaker.

② Check consciousness of the worker.

③ If breathing weakly, perform CPR (cardiopulmonary resuscitation) (cardiac massage: 30 times, respiration: twice).

④ After emergency measures such as CPR, contact a physician or emergency expert.

8) Transportation of components

Since crash accidents can occur while using cranes to install, repair or transport chambers, filter or cabinets, make sure there is no human or object underneath the components.

II. DRAWINGS OF BALLAST WATER MANAGEMENT SYSTEM

1. MECHANICAL DRAWINGS

BioVioletTM is composed of filtration system, UV system and control system. Figure 14 shows filter, by-pass line configured in parallel with the filter, and UV system. Figure 15 is the CAD drawing.
During ballasting operation, most of aquatic organisms and particles larger than 50 μm in the ballast water are strained out through the filter. Any aquatic organisms that are not removed during filtration process are disinfected while passing through the UV system. In addition, in order to remove aquatic organisms that may have survived in the ballast tank through ballasting operation, the ballast water is treated once again using the UV system during de-ballasting operation.

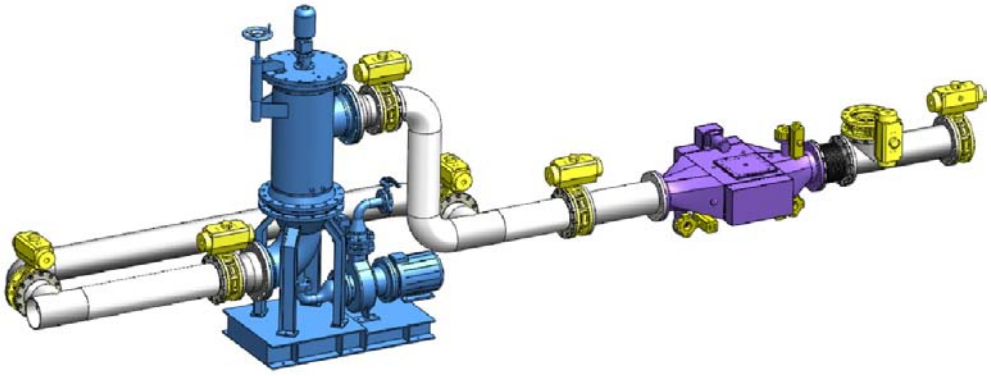


Figure 14. Three-dimensional drawing of BioVioletTM

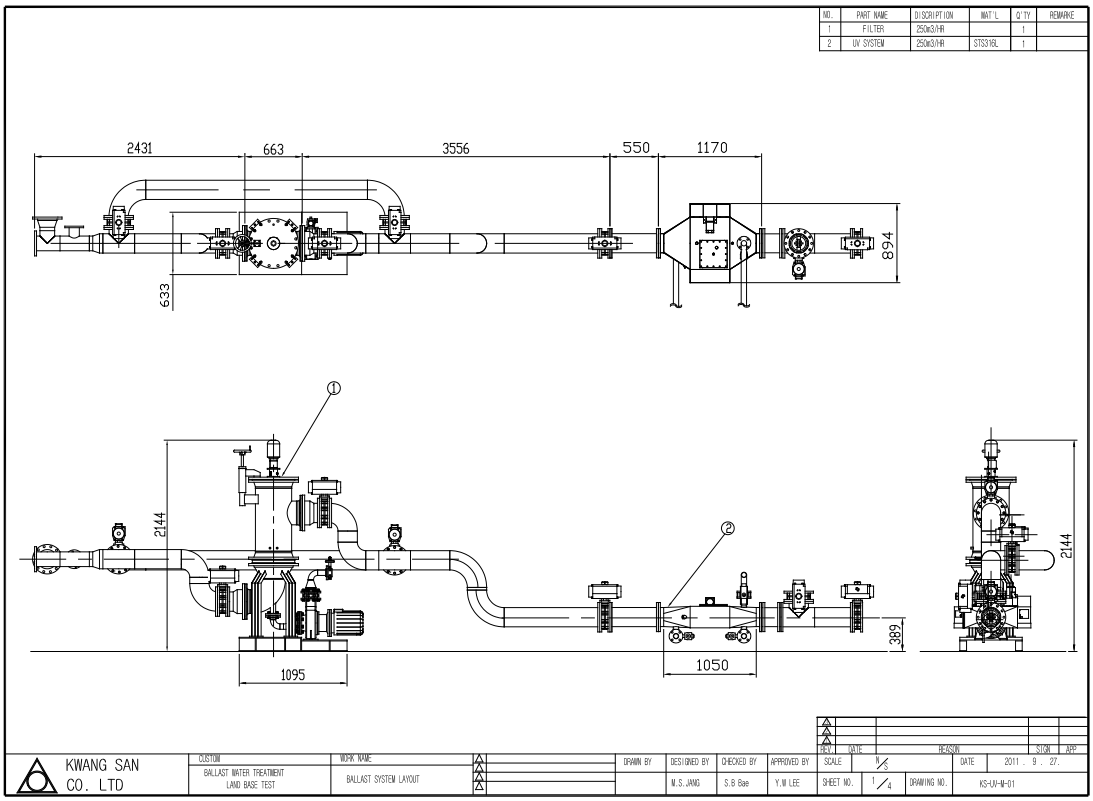


Figure 15. CAD drawing of BioVioletTM installed in the test facility

1.1 Filtration system

Filter increases disinfection efficiency of BioVioletTM by removing aquatic organisms and particles larger than 50 μm in the ballast water that come in through the ballast pump, preventing damages in quartz tube that protects the UV lamp.
50 μm, wedge wire type element is used for the filter. If differential pressure is equal to the setting point of 0.5 bar (can be changed), back-flushing pump is automatically operated to discharge aquatic organisms and particles larger than 50 μm that had been strained out by the elements.
Figure 16 shows three-dimensional drawing of the filter installed in the test facility, and Figure 17 is the CAD drawing.

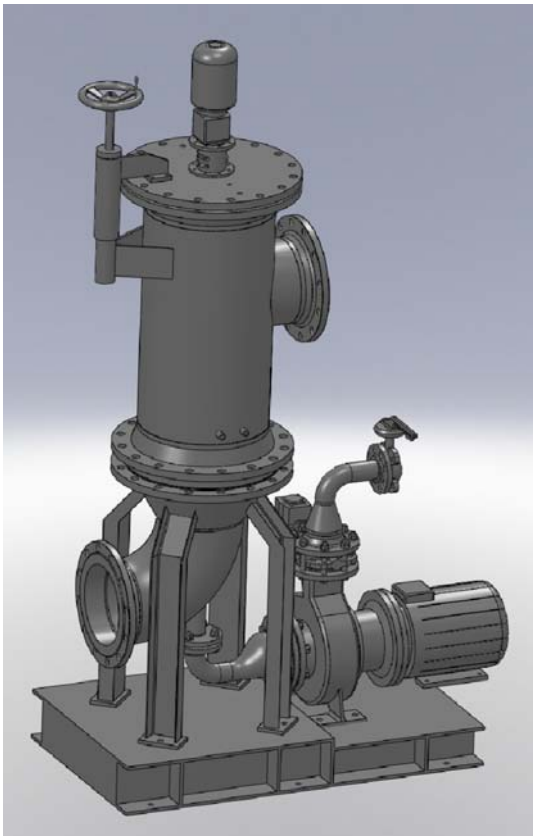


Figure 16. Three-dimensional drawing of the filter

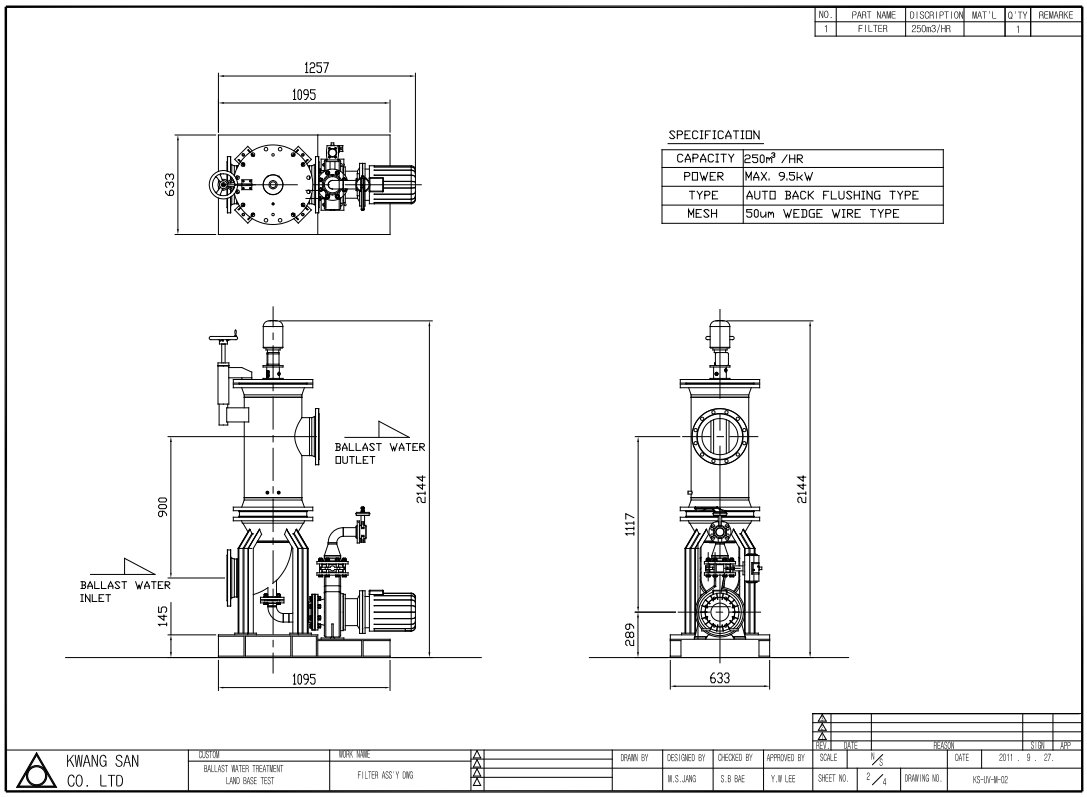


Figure 17. CAD drawing of the filter installed in the test facility

1.2 UV system

The UV system is composed of chamber body, medium pressure UV lamps, quartz tubes, cleaning device, and various components such as sensors. In the ballasting process, the UV system is used to disinfect aquatic organisms that are not removed by the filtration process. Also in the de-ballasting process, while filter is not used during discharge of the treated water, the UV system is used once again to disinfect aquatic organisms that were not removed by the ballasting operation or may recover in the treated water stored in ballast tank.

The UV system uses medium pressure/high intensity lamp for disinfection of aquatic organisms. Arc length is 550 mm and power consumption is 8.1 kW per lamp at maximum. Six lamps were installed.

To control lamp power by detecting UV light intensity used for disinfection of aquatic organisms during ballasting and de-ballasting operations, UV intensity sensors are installed, each at long and short distances from the lamp.

Figure 18 is the three-dimensional drawing of the UV system installed in the test facility, and Figure 19 is the CAD drawing.

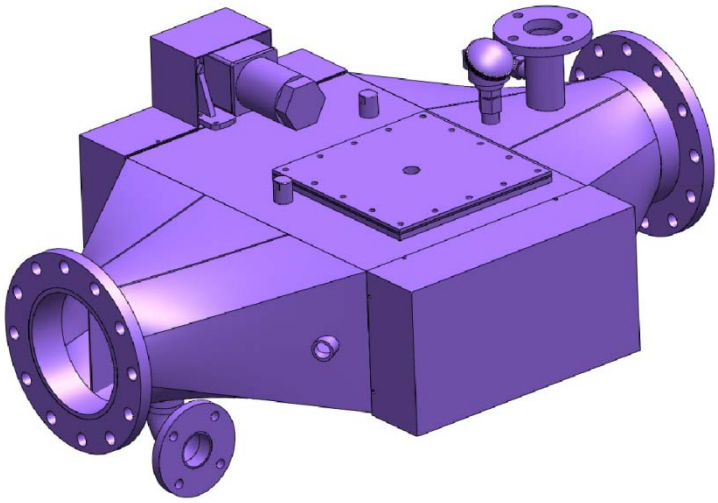


Figure 18. Three-dimensional drawing of the UV system

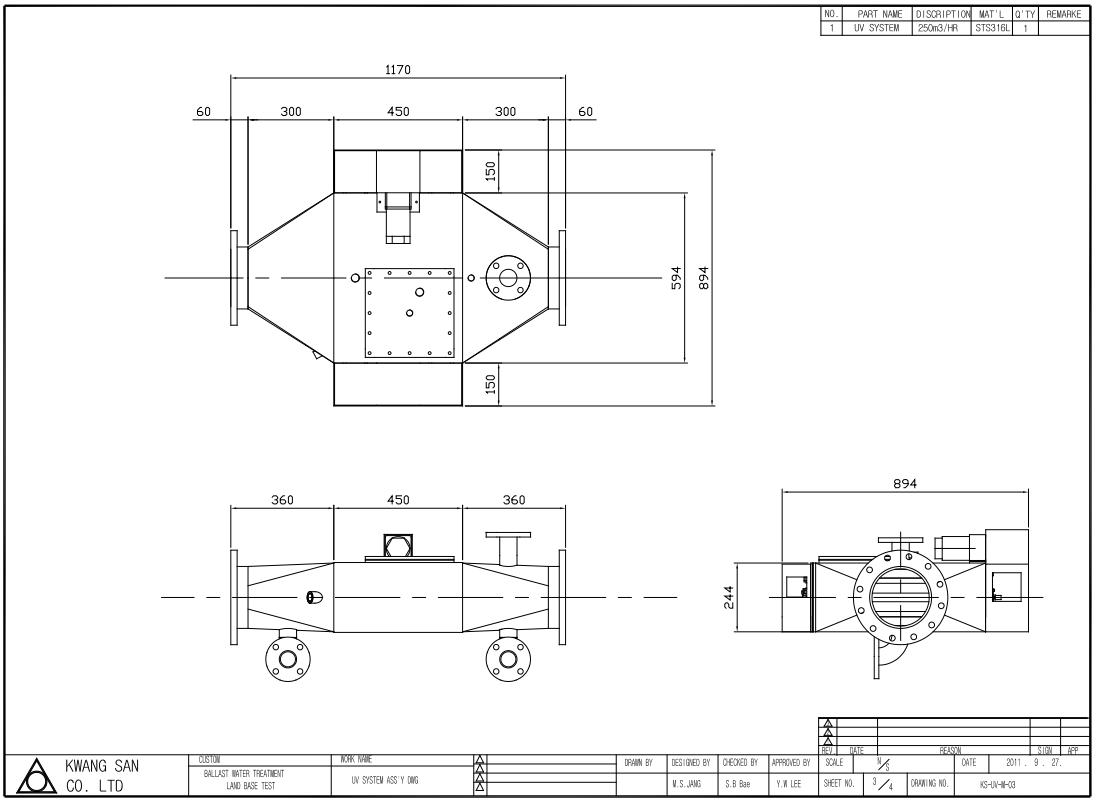


Figure 19. CAD drawing of the UV system installed in the test facility

2. ELECTRIC DRAWINGS

The following Figures are electric diagram and drawing of BioVioletTM.
In Figure 20, solid line represents power wiring and dashed line shows wiring of control and sensor signals.

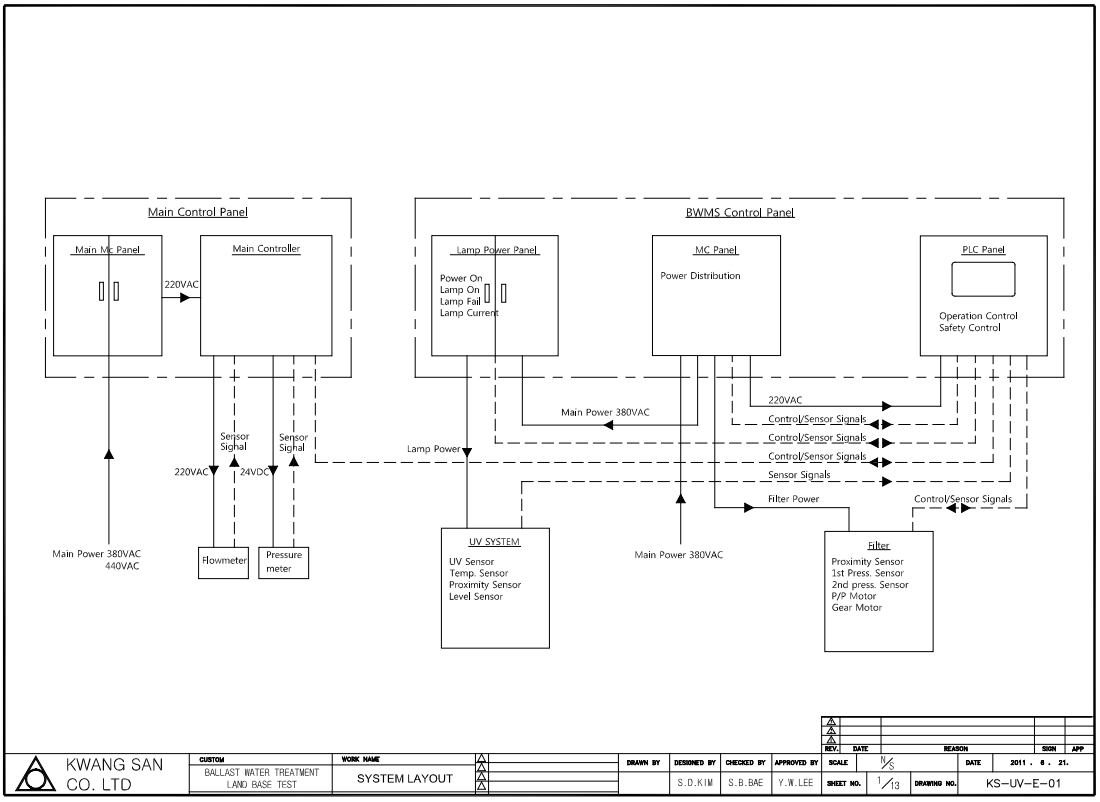


Figure 20. Electric diagram of BioVioletTM

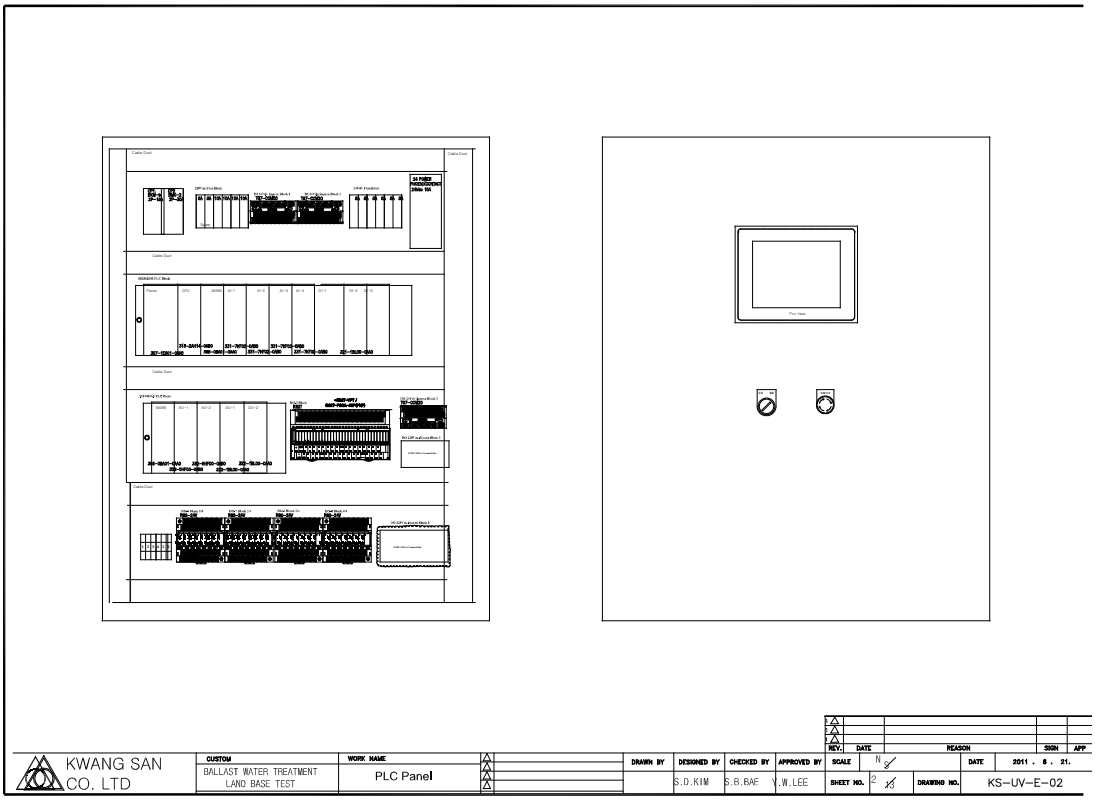


Figure 21. PLC panel

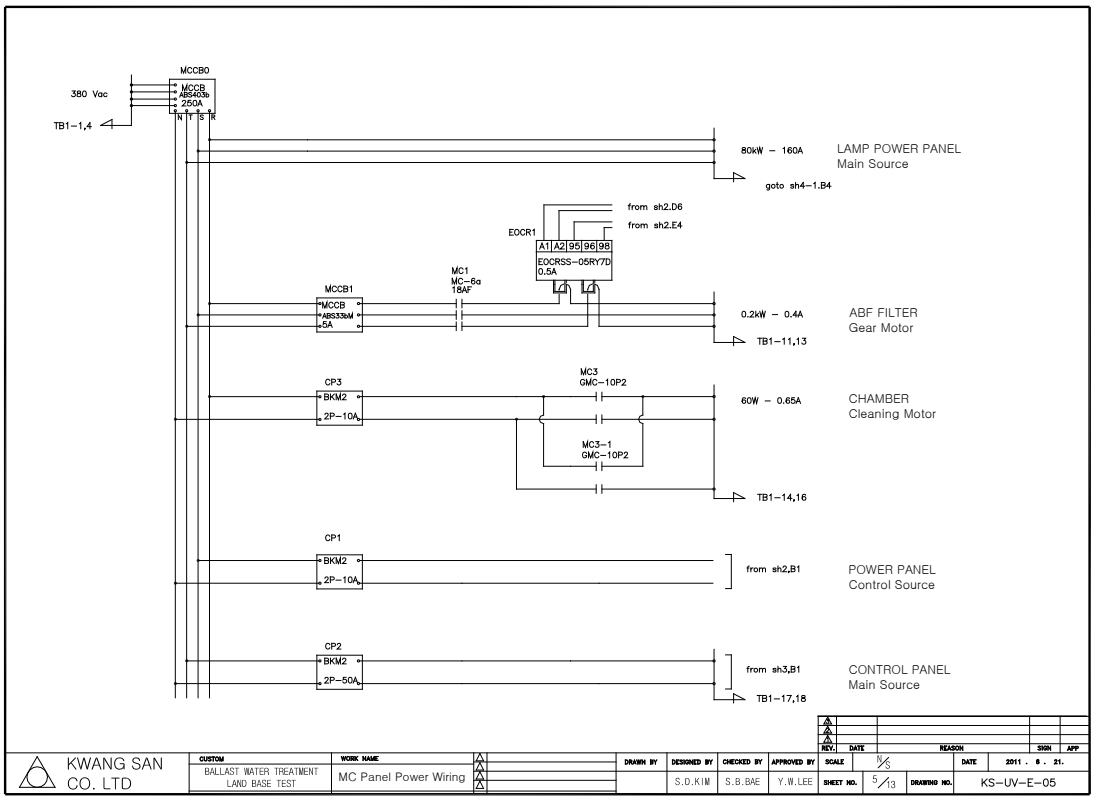


Figure 22. MC panel power wiring

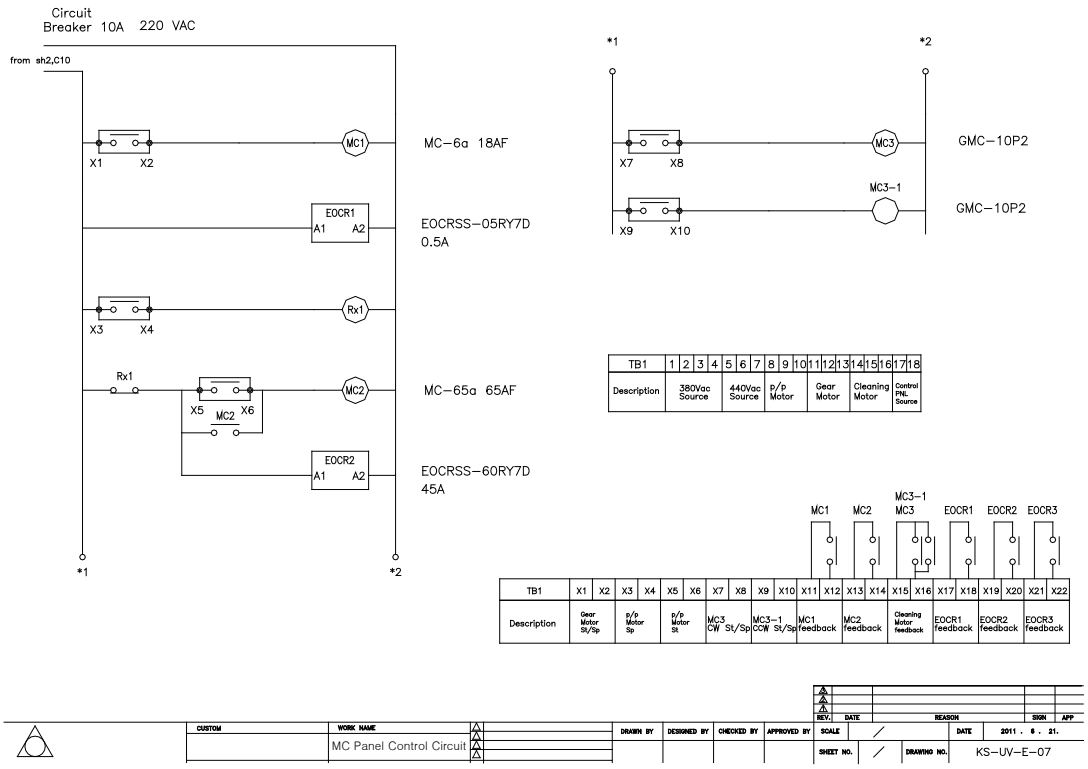


Figure 23. MC panel control circuit

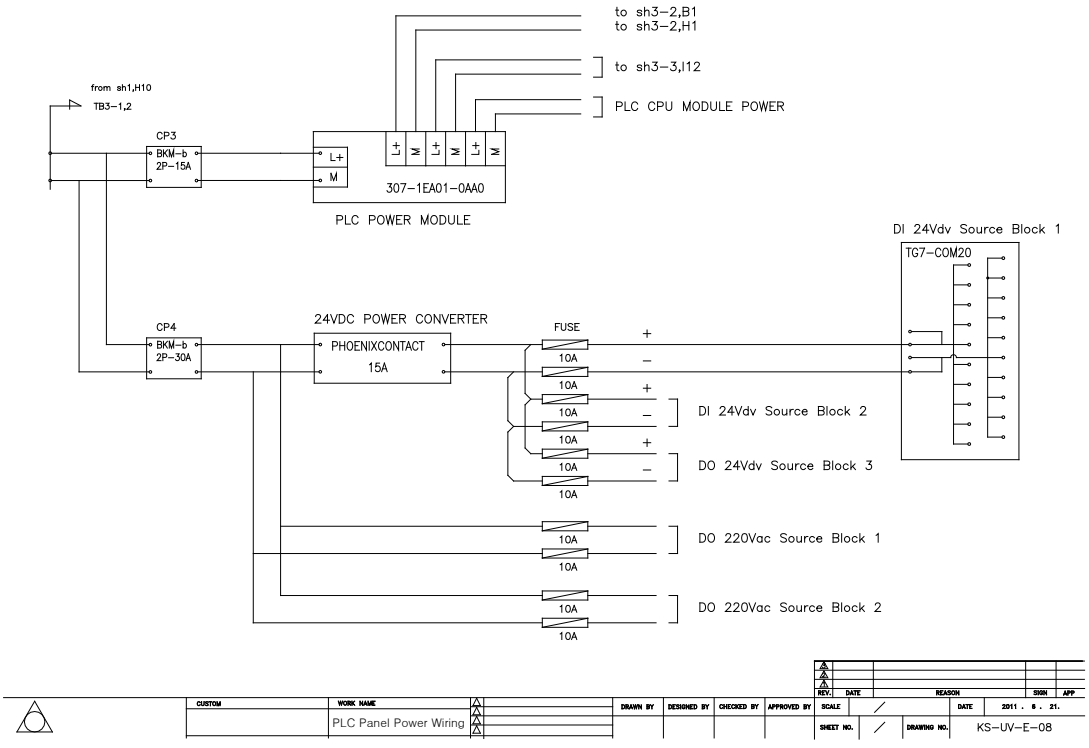


Figure 24. PLC panel power wiring

KWANG SAN CO. LTD

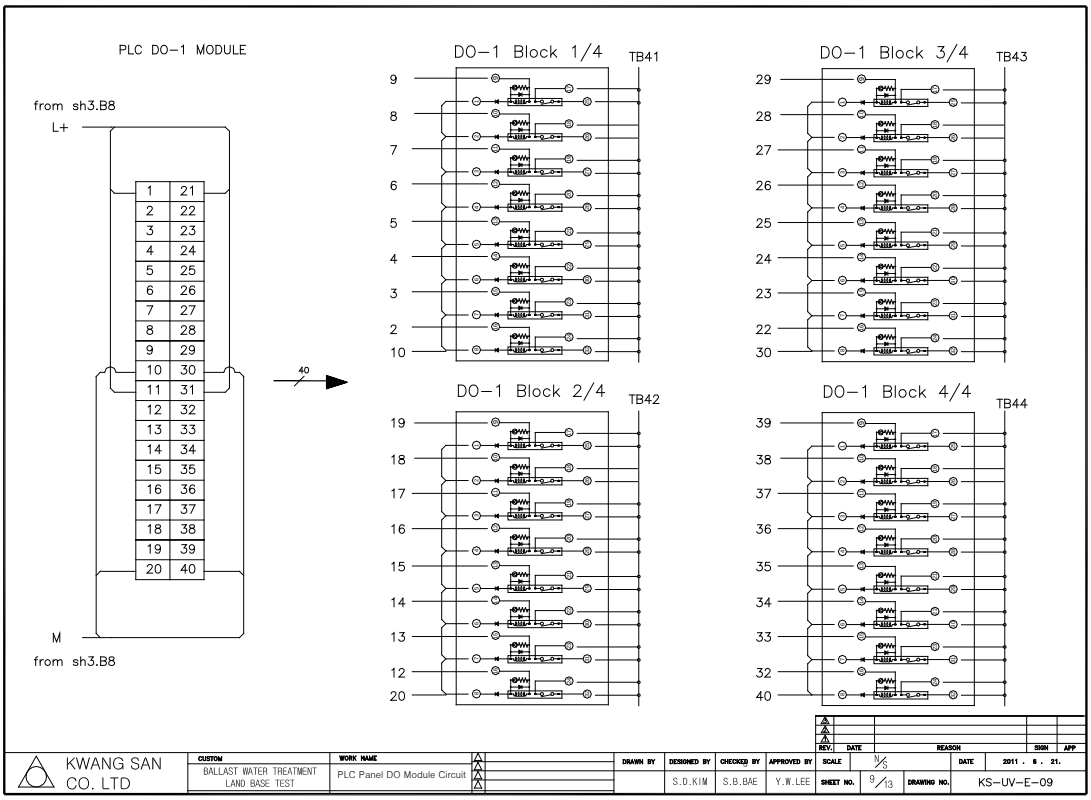


Figure 25. PLC DO-1 module circuit

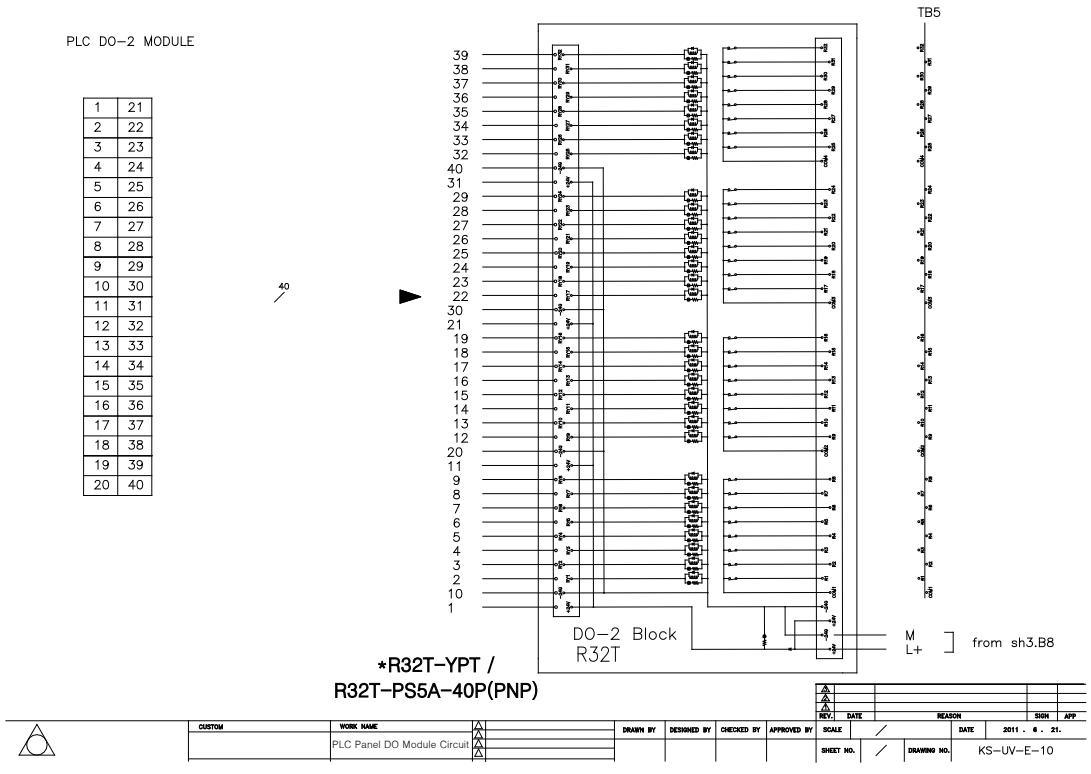


Figure 26. PLC DO-2 module circuit

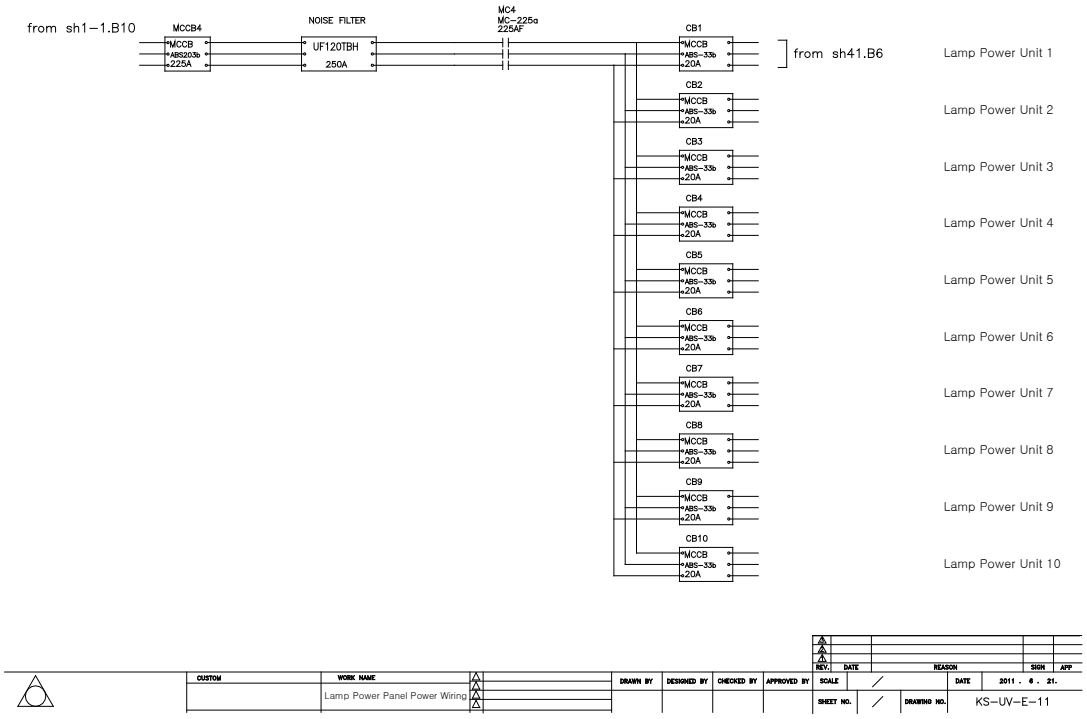


Figure 27. Lamp power panel wiring

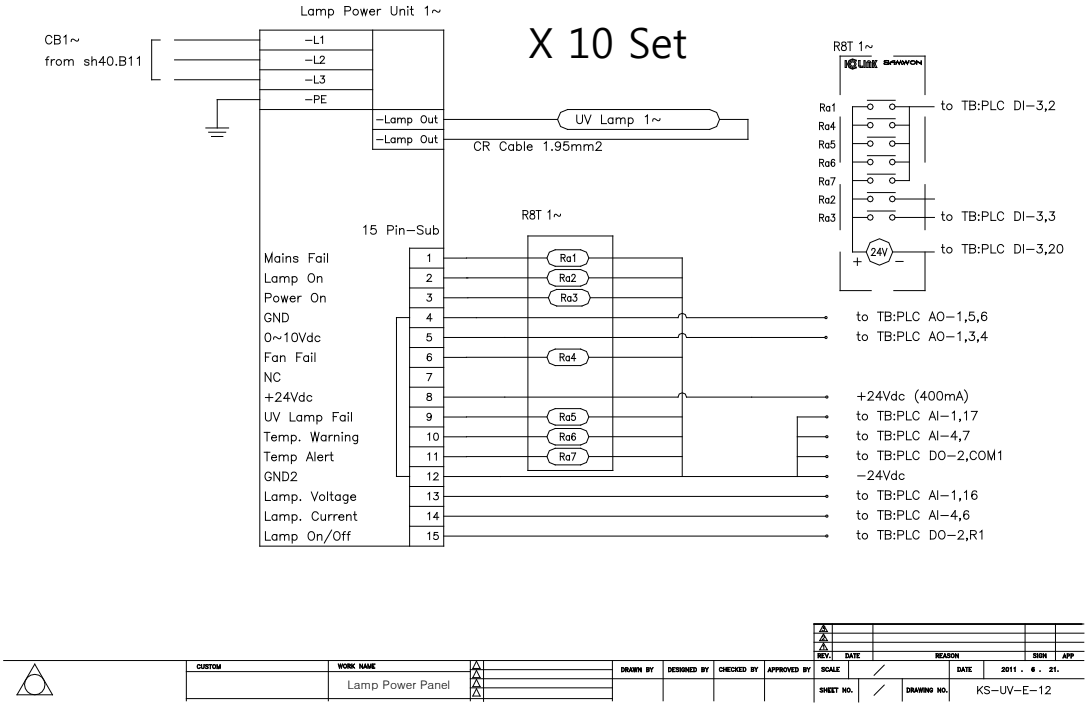


Figure 28. Lamp power panel (lamp power unit)

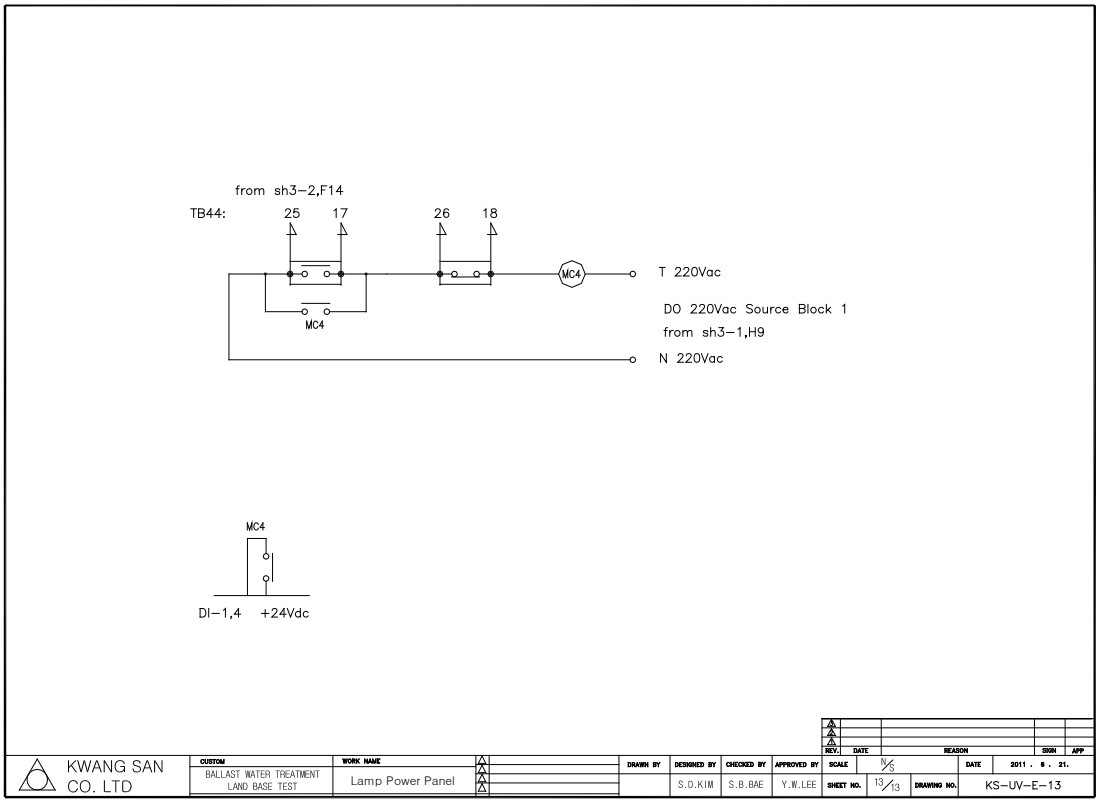


Figure 29. Lamp power panel

III. INFORMATION ON TEST FACILITY

1. POSITIONING AND SPECIFICATION OF TEST FACILITY

1.1 Drawing of test facility

Following Figures are three-dimensional and two-dimensional drawings of the test facility for testing of BioViolet™. The test facility is composed of 250 m^3 capacity tanks, ballast pump, flow meter, pressure meters, level transmitters, level switches, sea water pump, sampling ports, sampling tanks, agitators, piping, and main control panel. The main controller of the test facility, which corresponds to the ship's central control system, and the control system of BioViolet™ automatically conduct all operation processes based on mutual communication. In addition, all data during system operation are logged.

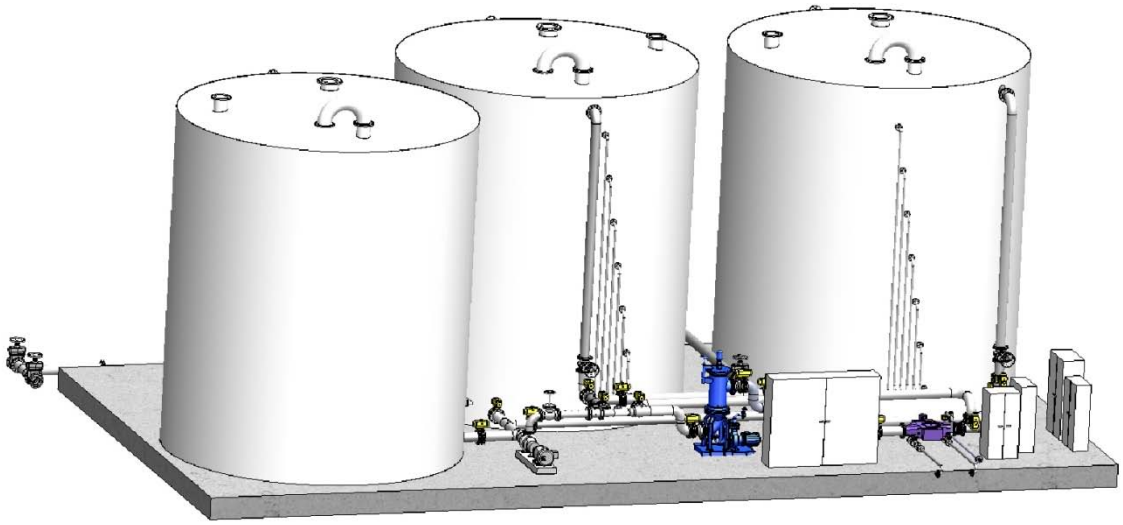


Figure 30. Three-dimensional drawing of the test facility

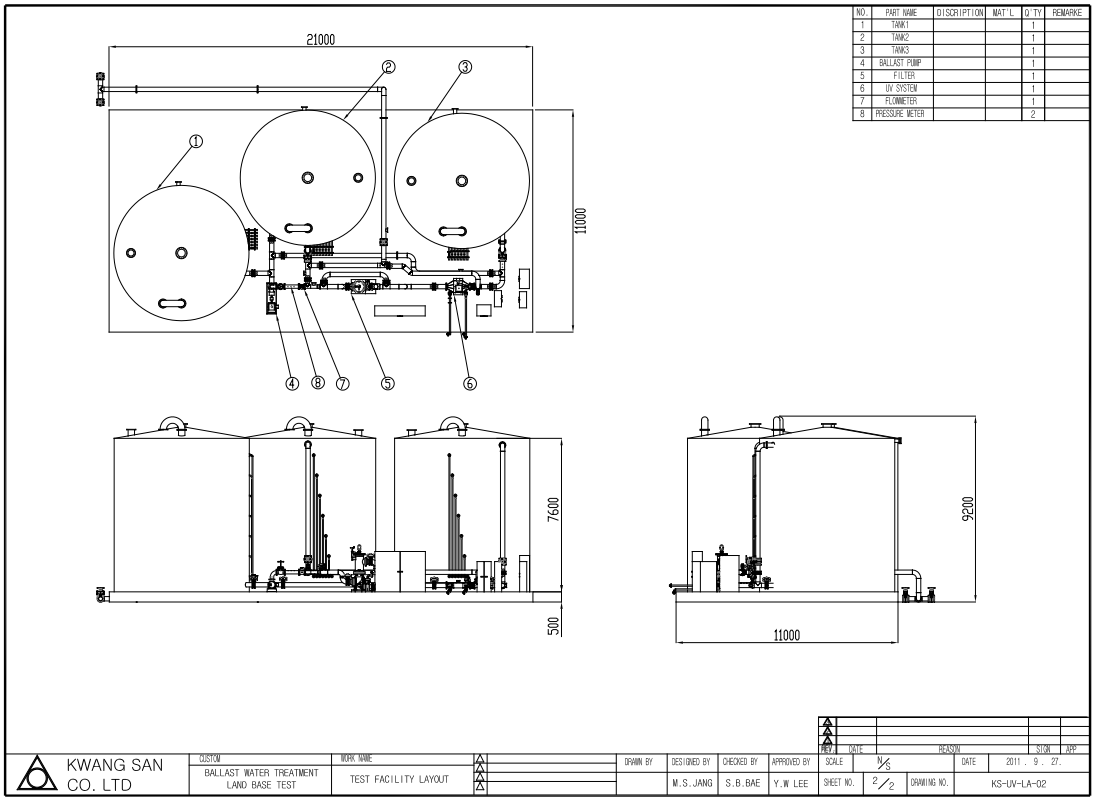


Figure 31. Two-dimensional drawing of the test facility

1.2 Positioning of components of the test facility

1) Tanks

The test facility includes three tanks, and capacity of each tank is 250 m^3. Tank 1 and tank 2 are used to manufacture test water and include sea water pipeline. An agitator is installed inside each tank. The agitator is operated to maintain test water condition during ballasting and de-ballasting operations. Also in each tank, sampling ports are installed at 7 points for each water level. Homogeneity of sea water in the tank is verified using such sampling ports.

2) Pipeline

Test water takes different path for each mode based on opening and closure of valves. To consider easy movement of the operator, such valves and pipeline facility are installed between the control system and tanks of BioVioletTM and test facility.

3) Ballast pump

Ballast pump is installed in front of flow meter and pressure meter.

4) Flow meter

Flow meter measures flow of water running in the pipe. Such flow data is used to control RPM (revolutions per minute) of ballast pump. Since flow meter must measure flow in all modes, it is installed between the pipeline, which separates to tank 2, and ballast pump.

Flow meter may not be included in case the developed BWMS can receive flow information from the ship's main control system, but otherwise, BWMS must include flow meter in its design.

5) Pressure meter

Pressure meter measures pressure of the main pipe. Since pressure must be measured in all modes, it is installed between the pipeline, which separates to tank 2, and ballast pump.

6) BioViolet™

Since the developed BWMS is only operated in treated mode, it is installed between filter and tank 3.

7) Distributing board and main control panel

For convenience of handling and quick response to emergencies, they are installed outside pipeline.

8) Sea water pump

Sea water pump that supplies sea water to tank 1 and tank 2 is installed outside the test facility (not indicated in the drawing).

9) Level transmitters

Level transmitter transmits test water level in each tank to the main control system. The water level data is used to determine starting and ending conditions for each mode.

10) Sampling ports

Sampling ports were installed at 7 points for each tank to check homogeneity of sea water in the tanks. Ports for sampling of treated water and control water during ballasting and de-ballasting operation were installed in four different spots of the pipeline.

11) Sampling tank (1 m^3)

Sampling tank was installed outside the test facility for sampling of aquatic organisms larger than 50 μm in the treated water. Sampling volume of this tank is automatically controlled.

1.3 Specification of test facility

Test facility	Specification
Tank	Materials: SS400 Diameter: 6,700 mm Height: 7,600 mm Capacity: 250 m^3
Ballast pump	Maker: SHIN SHIN MACHINERY CO., LTD. Model: EHC-200C Specification: 200 × 150 × 4.2 m^3/min × 30 m Power: 3 phase 440 VAC
Flow meter	Maker: TOSHIBA Model: GF630/LF600 Range: 19~631 m^3/h Power: 110/220 VAC Output: 4~20 mA
Pressure meter	Maker: KONICS CO., LTD. Model: PTF-30 Range: 0~10 kg/cm^2 Power: 15~35 VDC Output: 4~20 mA Accuracy: ± 0.3 % F.S(-10~50 °C)
Main control panel	Main controller: NI cRIO-9074 Sub controller: Master-K 300S
Level transmitter	Maker: HANLA LEVEL CO., LTD. Model: PL 40 Range: Absolute pressure 1,200 mbar~4 bar Relative pressure 175 mbar~4 bar Power: 12~28 VDC Output: 4~20 mA Accuracy: ± 0.3 % (at 20 °C)

2. IMFORMATION ON SAMPLING PROCEDURE

Sampling ports were installed for each water level of tank in order to check agitation status of test water and concentration of aquatic organisms. In addition, to conduct three samplings for each operating process, sampling ports were installed on the main pipe. A sampling tank with automatic adjustment of sampling volume was installed for sampling of aquatic organisms larger than 50 μm from the treated water.
All samples for chemical analysis, aquatic toxicity test, and efficacy test were collected from each sampling port. S1 represents test water sample, and S2 and S3 respectively represent control and treated water samples. Sampling on S2 and S3 was conducted three times, at the beginning, in the middle and at the end, during ballasting and de-ballasting operations. Each sample was sampled on Day 0 and Day 5 for efficacy test, on Days 0, 1 and 5 for chemical analysis, and on Day 5 for aquatic toxicity test.

2.1 Sampling ports

Figure 32 shows sampling ports and locations from which samples are collected.

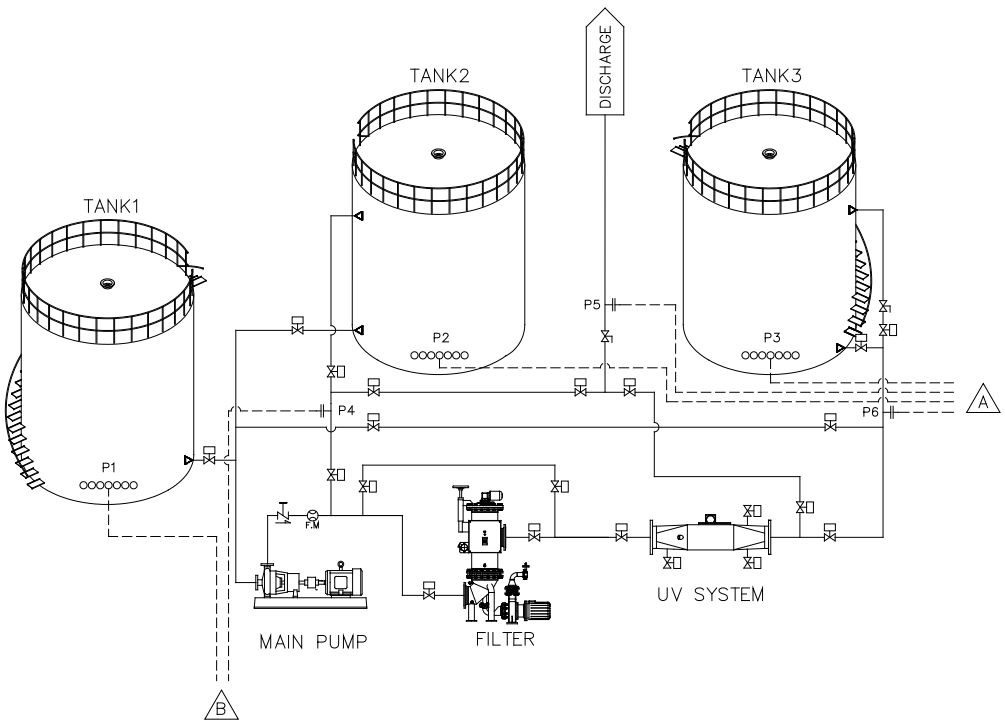


Figure 32. Sampling ports and locations

2.1.1 Sampling ports

Table 1 shows sampling ports installed in the test facility for collection of sample. From the table, P1~P6 are locations of sampling ports and S1~S3 are tags for sampling water collected on Day 0, Day 1, and Day 5. S1 is the tag for test water, S2 for control water, and S3 for treated water.

Table 1. Description of sampling

Sampling port	Sample tag		Description
	Ballasting	De-ballasting	
P1			Port to check organism concentration, turbidity and homogeneity in tank 1
P2	S1		Port to check organism concentration, turbidity and homogeneity in tank 2
P3			Port to check organism concentration, turbidity and homogeneity in tank 3
P4	S2		Port for sampling of control water during ballasting operation
P5		S2, S3	Port for sampling of treated and control waters during de-ballasting operation
P6	S3		Port for sampling of treated water during ballasting operation

2.1.2 Sampling location

Sampling locations in Figure 32 are indicated as **A** and **B**. Also, a separate sampling tank was prepared for sampling of aquatic organisms larger than 50 μm in the treated water. Valve of sampling tank is automatically operated by flow meter installed on the sampling line.
Figure 33 is the diagram of separately installed sampling tank.

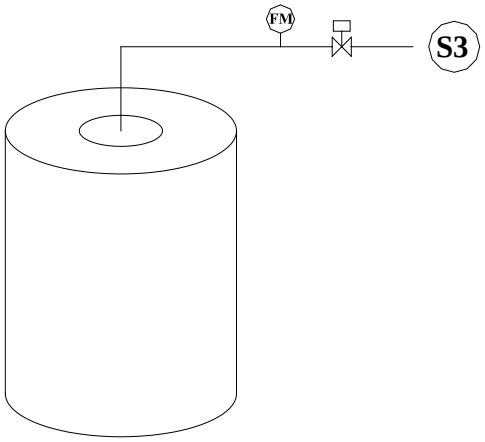


Figure 33. The diagram of separately installed sampling tank (1 m^3)

2.2 Sampling regime

2.2.1 Treated water

1) Aquatic organisms greater than or equal to 50 μm
   For enumeration of aquatic organisms, collect 1 m^3 of sample by sampling tank. For enumeration of sample (aquatic organisms), concentrate the sample using a mesh with diagonal size less than 50 μm.
2) Aquatic organisms greater than or equal to 10 μm and less than 50 μm
   For enumeration of aquatic organisms, collect 10 L of sample through sampling ports. Concentrate the sample using a mesh with diagonal size less than 10 μm.

2.2.2 Control water

1) Aquatic organisms greater than or equal to 50 μm
   For enumeration of aquatic organisms, collect 10 L of sample through sampling ports. For enumeration of sample (aquatic organisms), concentrate the sample using a mesh with diagonal size less than 50 μm.

2) Aquatic organisms greater than or equal to 10 μm and less than 50 μm
   Collect 10 L of sample through sampling ports. Concentrate the sample using a mesh with diagonal size less than 10 μm.

3. MAINTENANCE AND REPAIR PROCEDURES FOR THE TEST FACILITY

3.1 Maintenance

1) Tanks
   The interior of the tank is cleaned during each test period.

2) Valves
   Breakage of valves from seasonal or other reasons are regularly inspected. Conduct opening and shutting inspections prior to test.

3) Pipeline
   Inspect for leakage and breakage.

4) Panel
   Regularly inspect operation status of the breaker.

5) Electric system
   Inspect the electric system of the main controller prior to test.

6) Sensors
   Inspect operation status of sensors during each test period or with ‘Power ON’.

3.2 Repair procedures

1) Tanks

If agitator does not operate, inspect power line, hydraulic line and communication line. If applicable, replace the motor, hydraulic pump or communication line.

2) Valves

① Inspect air compressor.

② If opening and shutting of automatic control valves are not smooth, repeat manual opening and shutting of the valve several times.

③ Since manual valves of sampling ports can be easily damaged by seasonal reasons or external impact, immediately replace valves in case of leakage or unsmooth operation.

3) Panel

If power is not supplied to automatic control line, inspect the UPS (uninterruptible power supply).

4) Electric system

Immediately replace the breaker in case of unstable operation.

5) Sensors

Failure of sensors can cause serious problems in the control system. If signals are not inputted from the sensor, first check the wiring status of power input line and signal output line. Immediately replace sensors in case of no signal or unstable operation despite sound wiring status.